METROLINK

Integrated Transport. Integrated Life.

A5.17 Building Damage Report

Contents

Executive Summary

Buildings Ground Movement Impact Assessment

This document describes the industry standard three-phased ground movement impact assessment process that is undertaken on tunnelling and underground projects around the world, that includes Channel Tunnel Rail Link (CTRL), Dublin Port Tunnel, Crossrail and High Speed 2, and how it has been applied to the MetroLink project.

It does not cover the assessed impact of construction generated ground movements on utilities and services which are covered by a separate assessment due to there being over 50,000 utilities to be considered along the Metrolink route.

Phase 1 defines the buildings that could be potentially impacted by the project. It involves the calculation of the greenfield settlement contours using ground model parameters derived from published case history data and ground investigation work undertaken, and the identification of buildings that are:

a) enclosed within the 10mm contour or with a ground settlement slope > 1 in 500, and

b) enclosed within the 1mm contour and subject to 'special' considerations. E.g., Designated Protected Structures, or prominent or sensitive buildings.

Phase 2 involves the classification of the buildings into one of five pre-defined risk categories (see Table 4-4) based on the predicted maximum tensile strain that would be experienced by the building if it deformed to the predicted greenfield settlement profile. This approach is highly conservative since all buildings naturally have an inherent stiffness, but it provides a robust way of assessing with confidence the impact of ground movements. Those buildings that fall into a damage category of 3 or greater, and those subject to 'special' considerations are carried through to Phase 3.

Phase 3 involves the individual detailed assessment of each identified building to determine its behaviour using detailed information and sophisticated assessment methods; this usually includes a refined ground model, detailed structural surveys, and sophisticated finite element modelling types of analyses. It will be undertaken by the D&B contractor who can precisely define and refine the construction methodology, and benefit from greater design maturity, thereby being in a position to confidently use less conservative assumptions to assess the impact of construction generated ground movements. It is therefore likely that the Phase 3 assessed damage category of buildings will improve upon the results of the Phase 2 assessment. Based on the findings of the assessment, if considered necessary, protection measures will be designed to protect the building from unacceptable level of damage.

The three phases described above are split across the project life cycle and between the parties who will lead the ground movement impact assessment at each stage of the project life cycle. The Preliminary Designer undertakes the Phase 1 and an initial Phase 2 (termed as Phase 2a) Building Damage Assessment – covered by this document. Subsequently, the Detailed Designer for the Design & Build (D&B) Contractor will review and update the Phase 2a Building Damage Assessment, designated Phase 2b, taking account of the finalisation of the D&B contractor's construction methodology and planning, maturing design and refinement of geotechnical parameters and the ground model as further information become available, the final output of which will determine any buildings that should be progressed to Phase 3.

Prior to the commencement of this ground movement impact assessment, preliminary surveys have been carried out that have identified 219 'representative' buildings 30m either side of the proposed tunnel alignment. Some of these buildings have been designated as 'special' and will be taken through to the Phase 3 assessment regardless of their Phase 2 assessment results. In addition, buildings with deep basements or that are in close proximity of proposed excavations will also be subject to Phase 3 assessment regardless of the Phase 2 assessment results.

Phase 1 Buildings Assessment

Based on available case history data, an understanding of the ground conditions from available; records, papers and data, and ground investigation works undertaken for the MetroLink project, the Phase 1 assessment, including calculation of greenfield settlement contours is based on the following:

- the Airport and City tunnels will be formed using TBM method; and sub-tunnels/adits/caverns will be formed using non-TBM method.
- volume loss due to TBM works:
  - in superficial material (soft ground), or in rock with less than half-a-diameter rock cover above the tunnel crown: 1.5%
  - in rock with a minimum of half-a-diameter rock cover above the tunnel crown: 0.75%
- volume loss due to non-TBM works: 50% more than the corresponding values for TBM works.

For the station boxes, retained cuttings, portals, and shafts, the following construction methodology has formed the basis of the ground movement impact assessment undertaken and described by this document:

- all the station box excavations will adopt a top-down method of construction with retaining walls supported using high level props during construction to minimise ground movement effects.
- perimeter walls for the main station boxes will be constructed using diaphragm walling.
- perimeter walls for the sub-excavations adjacent to the main station boxes will be constructed using secant pile walls.
- portals, shafts and retained cuttings will be constructed using secant pile walls.
- dewatering of the ground outside of the site boundary is controlled during construction to prevent any adverse impacts.

The ground movements due to station box and retained wall construction have been estimated based on case history data provided by CIRIA 760 [Ref 4].

The Phase 1 green-field settlement contours calculated are provided in Appendix C. All the buildings enclosed by the 10mm contour or with a ground settlement slope > 1 in 500, and all the 'special' buildings enclosed by the 1mm contour have been carried forward to the Phase 2a assessment stage.

Refined Phase 2a Buildings Assessment

Refined volume loss values for the tunnelling works considering the advances in tunnelling equipment and control due to the capability of the TBM that will be used have been adopted for the Phase 2a building damage assessment (referred as the Refined Phase 2a assessment in this report) as follows:

- due to TBM works:
  - in superficial material (soft ground) or in rock with less than half-a-diameter rock cover above the tunnel crown: 1.0%
  - in rock with a minimum of half-a-diameter rock cover above the tunnel crown: 0.5%
- due to non-TBM works: 50% more than the corresponding values for TBM works.

The above volume loss values proposed for the TBM works are considered to be achievable for the envisaged ground and groundwater conditions taking account of the available TBM technology. For the non-TBM construction, current methodologies with instrumentation and monitoring from the surface providing information to inform the control at the face also improve the losses that can be anticipated and allows the volume loss values to be taken as 50% more than that of the corresponding TBM volume loss values. These values are considered moderately conservative.

In addition to the 219 'representative' buildings, the Phase 1 assessment identified a further 40 buildings qualifying for Phase 2 assessment as a result of being at risk of damage greater than Category 2. These are referred to as 'additional' buildings in this report and are listed in Table 5-4 and are also identified on the green-field settlement contour drawings provided in Appendix C. For these 'additional' buildings, the specific building heights have been taken account of and are assumed to be supported on shallow foundations with no basement.

On completion of the Refined Phase 2a assessment, all the 'representative' buildings were found to fall within Damage Category 2 or below. Further, except for AB11 & AB13 (terraced residential blocks south of Griffith Park

station), all the 'additional' buildings also fall into Damage Category 2 or below. For the two terraced residential blocks, AB11 and AB13, it is likely that the detailed Phase 3 assessment will bring the damage category level to below Damage Category 2. If not, it is considered an appropriate instrumentation and monitoring strategy during construction and that post MetroLink construction, repair (e.g. repointing, refer to table 4.3), would be a more economical and practicable treatment strategy for these buildings rather than more disruptive and intrusive pre-construction protection measures.Refer to

The other building of note is the Carrolls Building (B228) which is within 2m of the proposed Charlemont Station perimeter wall. While the ground movement impact assessment has concluded that protection works are not necessary, due to the proximity of the building to the station excavation, it is proposed, as a precaution, that provision at this time is made to be able to treat the ground beneath the building from the station site in the event ground movement mitigation is necessary.

With the exception of those buildings noted above, protective works are not anticipated for any of the buildings along the MetroLink route at this current time based on the information available.

Other Assets Ground Movement Impact Assessment (excludes utilities and services)

Using the calculated Phase 1 greenfield settlement contours, the impact of construction generated ground movements on bridges, railways, Luas, major roads, and airport assets has been assessed.

The industry standard three-phase ground movement impact assessment process, described above for buildings, will also be adopted by the MetroLink project for the aforementioned, noting that limiting movement criteria directly related to the specific asset concerned will be used to determine its progression through this staged assessment process.

Bridges

The maximum additional settlement and the differential settlement gradient that the assessed bridges can withstand without any intervention have been taken as 30mm, and 1 in 500 respectively; these values correspond to 50% of the typical limits for allowable movements for new bridge foundation design.

Bridges ST-4, ST-5 and ST-5a (see Table 6-1) that are in close proximity of the proposed Glasnevin Station have been predicted to settle more than 30mm based on the Phase 1 settlement predictions and are therefore likely to require mitigation. A possible solution is to support the bridge deck on temporary bearings/jacks during the construction of Glasnevin Station and adjust the bearing levels in response to the actual settlement experienced and recorded by monitoring instrumentation. Other bridges which are further away from the station box excavations are unlikely to require mitigation.

Iarnród Éireann

The Iarnród Éireann Maynooth and Cork lines will cross over the proposed MetroLink Glasnevin Station and will be designed as an integral part of the MetroLink station structure. For this reason, these lines are not considered by this ground movement impact assessment. Intervention is however likely to be required to adjust the track level (fettling of ballast) for the section of the Iarnród Éireann line passing adjacent to the proposed Tara Station during its construction.

An instrumentation and monitoring strategy with associated trigger levels will be developed and agreed with Iarnród Éireann to verify that the actual settlements on site confirm the ongoing safe operation of these services and the need for any required ballast fettling.

Luas Lines

No intervention is anticipated for the Luas lines due to ground movements generated by MetroLink construction. Similar to the approach for Iarnród Éireann lines, an instrumentation and monitoring strategy with associated trigger levels will be developed and agreed with the Luas operator to verify that the actual settlements on site confirm the ongoing safe operation of these services.

Roads

For roads in close proximity to the station boxes and retained cuttings, there is a possibility of surface cracking occurring during MetroLink construction, and localised surface repairs may therefore be required. Roads will need to be monitored and inspected regularly during the construction period, and maintenance and repair of the subbase and surface will be undertaken to maintain the stability and suitability of the road surface. This will be planned and agreed with the relevant highway authority. No mitigation measures are anticipated for roads away from the station boxes or retained cuttings.

Dublin Airport

No mitigations are anticipated for the aircraft stands and taxiway at Dublin Airport. Movement monitoring instrumentation and survey points will need to be installed across the areas that could potentially be impacted by construction generated ground movements to monitor any movement of the concrete pavement and any movement of the subgrade under the concrete pavement. Monitoring proposals will be developed by the D&B contractor and with DAA.

Cross Guns Quay Canal Lock

Cross Guns Quay canal lock and the associated structures (ST-5b) are not anticipated to undergo significant movement, however due to their relatively close position to the proposed MetroLink Glasnevin Station, there is a risk that jamming of the gates may occur due to relative movements on the vertical guide rail which could impede gate operations. It is therefore anticipated that the gates will need to be monitored to inform any necessary periodic gate adjustment in response to any movement experienced.

Other

No mitigation will be required for Ballymun Road petrol station (ST2) since it falls outside of the MetroLink settlement zone of influence, or for the Jim Larkin statue (ST-6) on O' Connell Street due to the limited size, structural form, and support to the structure.

Table 6-2 in the main body of this document summarises the assessed impact of MetroLink construction generated ground movements on bridges, railways, Luas, major roads, and airport assets.

1. Introduction

1.1 Background

MetroLink is the next phase of Dublin's integrated light rail network, which begins to the north of Swords at Estuary and runs southward to Dublin City Centre. From Estuary the route passes on viaduct over the Broadmeadow River and floodplain before descending into a retained cut, or cut and cover sections running alongside the R132 past Swords. It then rises to run at surface before passing under Dublin Airport in bored tunnel. The route then continues southwards in cut before crossing the M50 motorway on viaduct and descending towards Northwood Station. The route then continues in bored tunnel under the city centre before terminating just south of Charlemont.

This document presents the assessed impact of estimated ground movements generated by MetroLink construction on buildings and other assets, carried out as part of the Preliminary Design for the MetroLink project. It does not include the assessment of ground movement impacts on utilities and services which is the subject of a separate assessment due to there being over 50,000 utilities to be considered along the Metrolink route.

The proposed location and alignment of the MetroLink scheme is illustrated by Figure 1-1 (MetroLink Project Route Map) and Table 1-1 (Proposed MetroLink Stations). This alignment has informed the ground investigation undertaken and the developed Preliminary Design, including this ground movement impact assessment.

Figure 1-1: MetroLink Project Route Map

Table 1-1: Proposed MetroLink Stations

Element	Detail	Chainage Start (Approx)	Chainage End (Approx)	Length (m)	Element	Detail	Chainage Start (Approx)	Chainage End (Approx)	Length (m)
Seatown (Retained Cut)	BoH	2+799	2+824	25	Griffith Park (Underground)	BoH	13+761	13+779	17
	Platform	2+824	2+889	65		Platform	13+779	13+844	65
	BoH	2+889	2+898	8		BoH	13+844	13+876	32
Swords (Retained Cut)	BoH	3+767	3+792	25	Glasnevin (Underground)	BoH	14+825	14+835	10
	Platform	3+792	3+857	65		Platform	14+835	14+900	65
	BoH	3+857	3+865	8		BoH	14+900	14+926	26
Fosterstown (Retained Cut)	BoH	4+736	4+758	22	Mater (Underground)	BoH	15+589	15+616	26
	Platform	4+758	4+823	65		Platform	15+616	15+681	65
	BoH	4+823	4+832	8		BoH	15+681	15+698	17
Portal		6+066	6+097	31	O'Connell Street (Underground)	BoH	16+599	16+630	31
Dublin Airport (Underground)	BoH	6+999	7+016	17		Platform	16+630	16+695	65
	Platform	7+016	7+081	65		BoH	16+695	16+736	41
	BoH	7+081	7+114	32	Tara (Underground)	BoH	17+360	17+371	12
Portal		8+408	8+476	68		Platform	17+371	17+436	65
Dardistown	U Sections	9+022	9+087	65		BoH	17+436	17+463	26
		9+087	9+128	41	St Stephens Green (Underground)	BoH	18+397	18+429	31
Northwood Portal (Underground)	BoH	10+251	10+296	45		Platform	18+429	18+494	65
	Platform	10+296	10+361	65		BoH	18+494	18+511	17
	BoH	10+361	10+399	38	Charlemont (Underground)	BoH	19+282	19+316	34
Ballymun (Underground)	BoH	11+210	11+237	17		Platform	19+316	19+381	65
	Platform	11+237	11+302	65		BoH	19+381	19+397	16
	BoH	11+302	11+328	26					
Collins Avenue (Underground)	BoH	12+164	12+196	31					
	Platform	12+196	12+261	65					
	BoH	12+261	12+278	17					

Table 1-2 schedules the route sections and chainages with their corresponding relevant geotechnical units. (Chainages are approximate).

Table 1-2: Change in Geotechnical Units Along the Alignment

Chainage	Tunnel depth to ToR (m)	Geotechnical Unit	Type of excavation	Chainage	Tunnel depth to ToR (m)	Geotechnical Unit	Type of excavation
1+238 – 2+184	0 +2	QBR	Embankment	11+238 – 11+638	5-15	QBR/BOD/UWR/CLU	C&C
2+184 -6+096	0 – 6	QBR-QAG-CMUP	C&C + at grade	11+638-12+438	16-25	CLU/BOD/UWR mixed face	TBM
6+096-7+638	14-17	BOD/UWR/QBL mixed face	TBM	12+438-13+388	22-24	CLU/BOD/UWR mixed face	TBM
7+638-8+238	17-25	BOD/UWR/CMUP mixed face	TBM	13+388-14+138	23-30	CLU/BOD/UWR mixed face	TBM
8+238-8+688	22-24	CWA-CTO	TBM	14+123-15+658	24-34	CLU	TBM
8+688-8+888	23-24	CTO/BOD/UWR/QBL mixed face	TBM	15+658-17+038	23-25	CLU/BOD/UWR/QBR Mixed face	TBM
8+888-9+158	24-25	QBL	TBM	17+038-17+138	24-25	QBR	TBM
9+158-9+638	24-17	CTO/QBL	TBM	17+138-17+838	20-27	CLU/BOD/UWR/QBR Mixed face	TBM/ C&C
9+638-10+738	17-0	QBL/QBR	C&C	17+838-18+588	24-27	CLU	TBM
10+738 – 11+238		QBL/QBR	M50 viaduct + embankment	18+588-20+538	23-28	CLU	TBM
				20+538-21+238	22-29	CLU	TBM

Note:

C&C = Cut and Cover
TBM = Tunnel Boring Machine
ToR = Top of Rail
For geotechnical unit acronyms refer to 1.2.2

1.2 Acronyms

1.2.1 General

ALS	Accidental Limit State
DL	Dead Load
ELPLA	Elastic, perfectly Plastic model
EN	Euro norms
EPB	Earth Pressure Balance
FEM	Finite Elements Method
FS	Factor of Safety
GIR	Geotechnical Interpretive Report
GL	Ground Loss
GSI	Geological Strength Index
HB	Hoek-Brown
ITA	International Tunnelling and Underground Association
LEM	Limit Equilibrium Method
LL	Live Load
MC	Mohr – Coulomb
N/A	Not Applicable
OLM	Old Metro North
QX	Made ground
SLS	Serviceability Limit State
SW	Self Weight
TBM	Tunnel Boring Machine
ULS	Ultimate Limit State

1.2.2 Geotechnical Layers - Glossary of Terms

Qx	Made ground
QAG	Alluvial Sands and Gravels
QBRs	Pre-Glacial Sands & Gravels
QBR	Broun Boulder Clay
QBL	Black Boulder Clay
BoD	Base of drift deposits
CLU	Lucan Formation
CTO	Tober Colleen Formation
CWA	Waulsortian Formation
CMLO	Lower Member Malahide Formation
CMUP	Upper Member Malahide Formation
UWR	Upper weathered rock

1.3 XDisp Software

1.3.1 General

The software package XDisp has been used to assess ground movement impacts generated by:

- tunnelling;
- wall installation and bulk excavation from station box construction; and
- wall installation and bulk excavation from cut and cover and retained cut construction.

XDisp stands for Excavation Induced Ground Displacements. XDisp calculates the ground movements induced by tunnelling, embedded wall excavations or mining works in terms of 3D displacements, settlements, and horizontal movements. It can subsequently perform building damage assessments using the calculated ground movements.

Tunnels are specified as cylindrical excavations in the ground. Tunnelling induced settlements are assessed based on inverted Gaussian distribution curves defined by user specified volume loss and trough width parameters. XDisp will then use this to define the settlement profile at the surface or at a specified depth.

Embedded wall excavations are defined in plan as polygons with a level at each corner, or as circles with a single base level. Each wall of a polygonal excavation, and each circular excavation is assigned horizontal and vertical ground movement curves that are used to calculate ground displacements; the normalised curves developed from case history data and given in CIRIA Report C760 “Embedded retaining walls – guidance for economic design” [Ref. 4] have been used by this ground movement impact assessment, enabling settlements and horizontal ground movements to be estimated for the construction of retaining walls that will be constructed to form station boxes and retained cuts.

Ground movement parameters and coefficients are inputted into XDISP which then overlays a 2m x 2m grid on top of the rail alignment, calculating the settlement trough and wall movement curves. These values are then interpolated by the software to generate contours of ground movement at the surface. In any location where the displacements caused by two separate structures overlap, such as areas above the tunnel but close to the walls of a station box, the principal of superposition is used and the displacements caused by each structure are combined. An example output is shown by Figure 1-2 which can then be exported from the software to create settlement contour drawings.

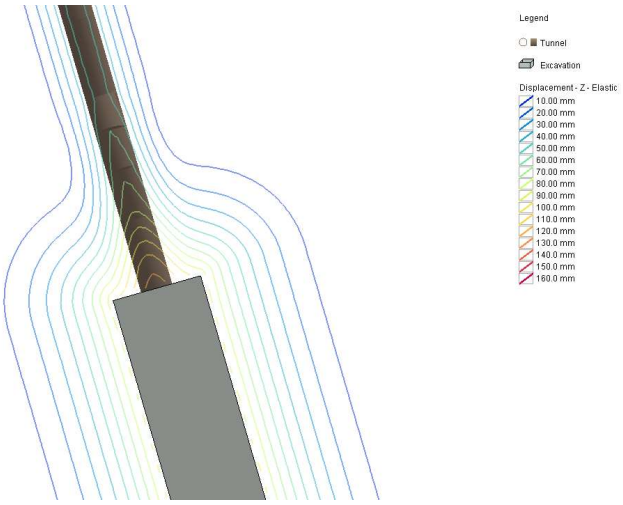


Figure 1-2: Example Output from XDisp

A building damage assessment can then be subsequently performed using the Burland (1995) assessment method. Buildings are specified by their locations including their overall bending properties; with lines of displacement points and a set of damage category tensile strains that define the thresholds of each damage category.

The estimated ground movements and their corresponding slope between specific points (differential settlement) can also be used to determine the impact on other built environment assets such as bridges, railways, highway etc.

1.3.2 Ground Movements at the Corners of the Excavation

Ground movements due to the excavation works associated with underground box construction are assessed using the normalised displacement curves from CIRIA Report C760. These curves are derived from case history data and applicable for long walls under plane strain conditions, thereby requiring that assumptions are made to estimate construction generated ground movements at the corners of underground box constructions. XDisp allows two options to assess the ground movements at these corner zones.

Option 1: without considering the corner stiffening effects

In this option, the displacements that are calculated for positions that are within the arc of an excavation corner (i.e., positions that cannot be reached by drawing a perpendicular line from any side of the excavations) are based on the distance measured to the corner. Hence the magnitude of the settlements at positions P1 and P3 in Figure 1-3 will be calculated to be equal. The calculation of the horizontal ground movements for a displacement point that is located in the arc of a corner (Refer to Figure 1-4), and a distance ‘d’ from the corner, depends on the magnitude and directions of the horizontal movements at the adjacent sides for points on an equivalent distance ‘d’ from those sides; these are estimated using the equations given in Figure 1-4.

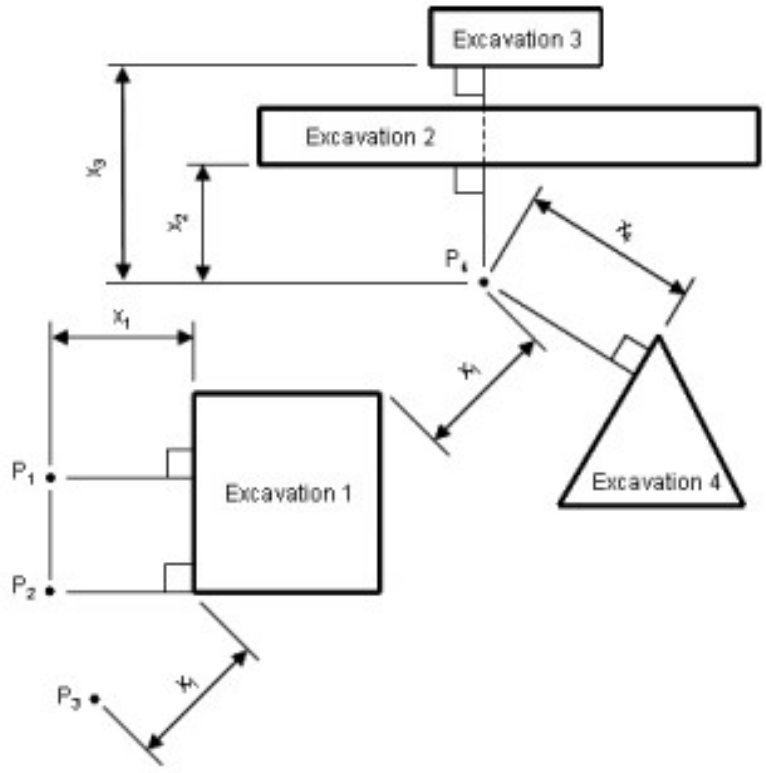
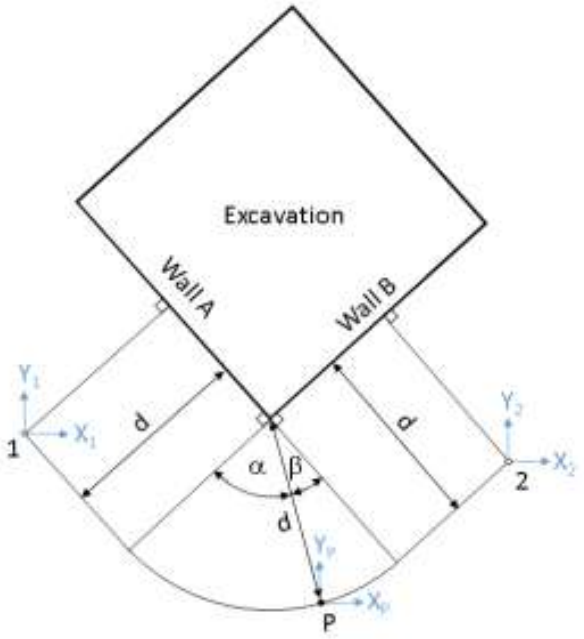


Figure 1-3: Plan of Multiple Excavations (XDisp Software)



If P is a displacement point in the arc of the corner of an excavation, then its horizontal ground movement components (X_p and Y_p) are given by:

$$X_p = p_a X_1 + p_b X_2$$

$$Y_p = p_a Y_1 + p_b Y_2$$

where, for unstiffened corners,

$$p_a = \frac{\beta}{\alpha + \beta}$$

$$p_b = \frac{\alpha}{\alpha + \beta}$$

Figure 1-4: Displacement Assessment at Excavation Corners (XDisp Software)

Option 2: considering the corner stiffening effects

In Option 1 above, the normalised ground movements curves from CIRIA 760 are used to represent the 100% ground movement profile in all areas. However, this is a conservative approach for box type excavations since the increased stiffness at the corner zones reduces the ground movements generated around the corners of the box excavation. For the ground movement impact assessment, Option 1 may not provide conservative results as the corner stiffening effect could introduce greater differential settlement on a building spanning across the corner zone. XDisp provides an option to consider the corner effect and adjust the ground movements based on the method suggested by Fuentes and Devriendt [Ref. 6]. The implementation of this method in Xdisp is shown in Figure 1-5.

The input parameters required for this method apart from the geometry are

- in zone i & v, plane strain ground movement applies i.e.,100% of the CIRIA 760 curves;
- p1%: percentage of the plane strain ground movement along the line which is normal to the wall adjacent to the corner (refer to Figure 1-5 and Plot 1)
- p2%: percentage of the plane strain ground movement along the line which is at an angle Θ/2 to the line along which p1% is calculated (refer to Figure 1-5 and Plot 2)
- In zone ii and iv, linear reduction of the percentage of plane strain ground movement from 100% to p1% apply
- In zone iii, the % of contribution from the adjacent walls are determined from Plot 3 in Figure 1-5.

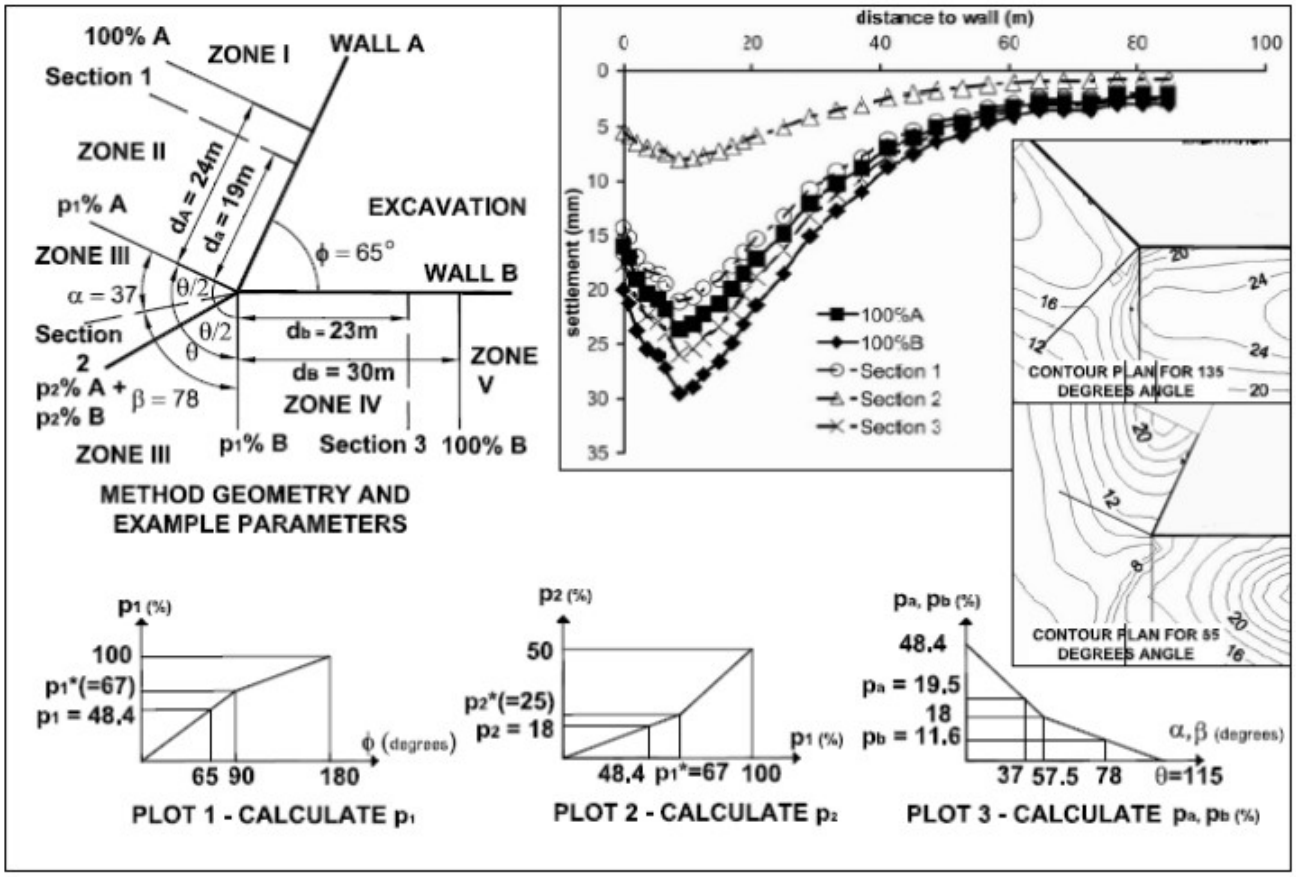
For the rectangular station boxes associated with the MetroLink scheme with 90° corners, the following values have been adopted: p1=67%, p2=30%, and the distance to zone i/zone v from the corner has been taken as half the width of the station box.

Approach Adopted in this Report

For the assessment carried out in this report, Option 1 has been adopted to assess the ground movements at the corners of the bulk excavations.

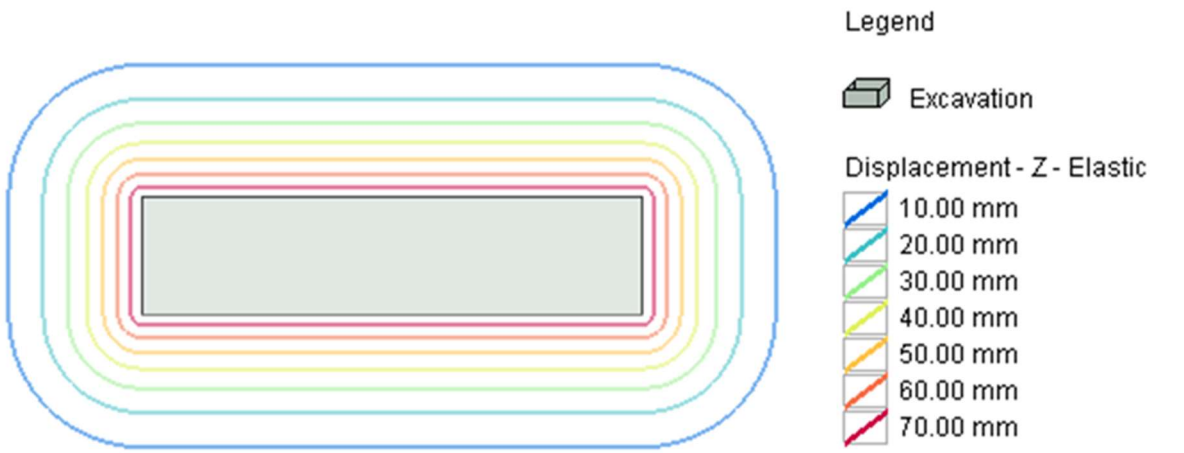
Additional sensitivity analyses have been carried out on selected buildings located close to the corners of the proposed station boxes with Option 2 (invoking the corner stiffening effect) to verify the resulting building damage category is unaffected. The results are compared in Section 5.3 with the corresponding results obtained from applying the Option 1 methodology.

Typical contour output for a box excavation adopting both Option 1 and Option 2 are shown by Figures 1.6a and b respectively.

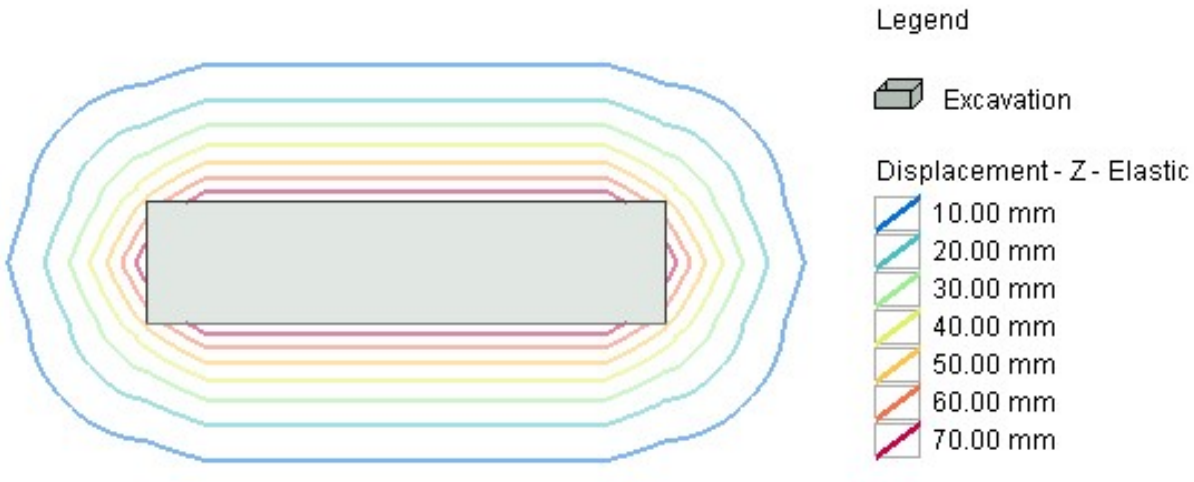


Plot	Input	Zones I and V	Zones II and IV	Zone III
1	p_1^* and ∅	X	✓	✓
2	p_1^* and p_2^*	X	✓	✓
3	p_1^*, p_2^*, α, and β	X	X	✓
Equations		$p = \%A$ or $p = \%B$	$p = p_1 + (100 - p_1)\frac{d_a}{d_A}\%A$ or $p = p_1 + (100 - p_1)\frac{d_b}{d_B}\%B$	$p = p_a \times \%A + p_b \times \%B$

Figure 1-5: Displacement Assessment with Corner Stiffening Effects (Xdisp Software)



a) corner stiffening effect not invoked (Option 1)



b) corner stiffening effect invoked (Option 2)

Figure 1-6: Settlement Contours Around Box Excavation Derived From XDisp Analysis

2. General Description of Underground Structures

2.1 TBM Tunnels

The MetroLink tunnel alignment will consist of a single bore bi-directional tunnel constructed by means of a tunnel boring machine (TBM) that will be specified and designed to enable tunnelling generated ground movements to be minimalised. The tunnels have been designed with an internal diameter of 8.5m, determined by the rolling stock kinematic clearance, and railway services requirement (See Figure 2-1).

From a review of the expected geology and hydrogeology along the tunnel alignment, the construction and logistics constraints, and the anticipated TBM operational procedures, it is considered likely that a variable density (VD) TBM or a Mix Shield TBM will be selected. It therefore follows that the main characteristics of the TBM required to meet the tunnel requirements will be as follows.

- Diameter of the cutter head: 9.53m
- Diameter of the frontal shield: 9.50m
- Diameter at the rear of the shield: 9.48m
- Shield length (approx.): 10.00m
- Diametrical gap (outer diameter of excavation): 0.33m
- Minimum radius of curvature: 300m (Note: minimum alignment curve radius is 350m).

The tunnel lining itself has been assessed for all relevant ground loading conditions, manufacturing loads (demoulding, storage, and transportation) and segment installation during ring-build. The main characteristics of the segments are:

- Typology: Universal ring.
- Thickness: 35 cm.
- Concrete class: C40/50
- Reinforcement: Steel bars class C + steel fibres (Model Code FRC 4e)
- Fire protection: Polypropylene fibres

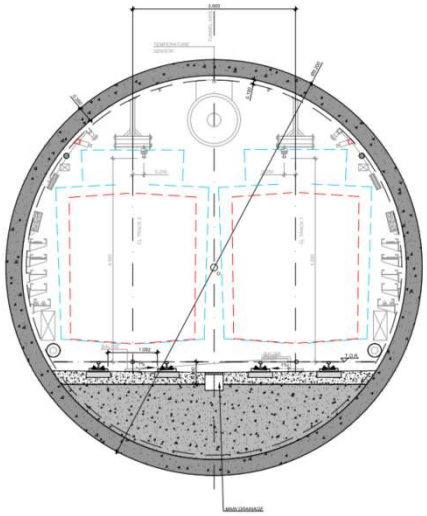


Figure 2-1: TBM Tunnel Geometry

2.2 Non-TBM Underground Structures

Five galleries, comprising two ventilation and three emergency galleries will be required, connected to the main tunnels within the curtilage of Dublin Airport and at Albert College Park Intervention Shaft. These will enable

ventilation of the tunnels, will be designed for pedestrian evacuation in an emergency scenario, and will accommodate emergency services intervention.

The location, length, and purpose of each gallery is summarised by Table 2-1 below.

Table 2-1: Gallery Arrangement.

From	To	Location	Type	Length (m)
8+408	8+093	Parallel to main tunnel right side	Escape route*	315
8+408	7+826	Parallel to main tunnel left side	Ventilation*	582
12+790	_	Intervention shaft	Ventilation	35
12+840	_	Intervention Shaft	Escape route	35
19+420	19+722	Termination tunnels beyond Charlemont station	Escape Route	302

*Although airport ventilation and evacuation tunnels might be formed using TBMs, for preliminary ground movement impact assessment it has been conservatively assumed that they will be formed using a non-TBM method.

The intervention shaft will be located at approximately chainage 12+800. The purpose of this shaft is to comply with the tunnel fire safety strategy which establishes a maximum distance between intervention/evacuation points, and to provide appropriate tunnel ventilation.

Station box structures have been designed as concrete boxes with several internal levels. The design is based on using diaphragm walls for temporary and permanent ground support, and groundwater control. All the sub-excavations adjacent to the main stations box excavations are designed using secant pile walls for temporary and permanent ground support, and ground water control. Portals, shafts and retained cuttings are designed using secant pile walls supported by internal props during construction, where possible permanent props are used in the temporary case.

3. Geological and Geotechnical Overview

3.1 Geological Overview

The MetroLink tunnels will be constructed typically in a sedimentary sequence formed by a Carboniferous basement, with mudstones and limestones, and minor sandstones and shales, covered by glacial, fluvioglacial, fluvial, and recent marine deposits of Quaternary age.

The solid (bedrock) geology of the region comprises a sequence of sedimentary rocks that are assigned to the Lower Carboniferous period, ranging in age from Courceyan to Brigantian. The geological sequence was originally deposited in a marine sedimentary basin known as the Dublin Basin which formed during continental drifting in Lower Carboniferous times. Differences in the amount and rate of opening and deepening of this basin led to lateral facies variations so that rock type can change considerably within one stratigraphic horizon across the region. Within the basin the Carboniferous rocks are gently folded so that they form a series of anticlines and synclines trending east-northeast and west-southwest, with bedding dipping north-northwest or south-southwest.

Quaternary Soils are essentially unconsolidated material overlying bedrock. The soils include topsoil, made ground, drift and alluvial and recent marine sediments. Drift is a general term applied to all mineral material (clay, sand, silt, boulders) transported by a glacier and deposited directly as till or as fluvioglacial deposits by running water emanating from the glacier. It generally applies to deposits laid down during the Pleistocene glaciations, although drift can also be included under Quaternary deposits.

The drift geology of the area principally reflects the depositional process of the last glaciation when an extensive ice sheet extending into the Irish Sea covered the region. Typically, during the ice advance, boulder clays were deposited sub-glacially as lodgement till over the eroded rock head surface, whilst moraine deposits were laid down at the glacier margins. Subsequently, with the progressive retreat of the ice sheet from the region, fluvio-glacial deposits were laid down in places by melt waters discharging from the front of the glacier.

The Glacial Deposits mainly include firm to very stiff, silty, sandy, gravelly clay (lodgement till) with sparse cobbles and boulders and 200-600mm thick embedded strata. The glacial deposits comprise lenses of fine to coarse sub-rounded to sub-angular gravel and cobbles with scarce, silty and fine, sandy matrix and occasional boulders (sub-glacial channels, fluvial–glacial, braided rivers and outwash deposits). The till is locally named Dublin Boulder Clay and it is traditionally subdivided into brown and black strata (Farrell et al., 1995) [Ref. 1].

Carboniferous Sequence rocks are the most common rock types in Co. Dublin. They are delimited to the south by a faulted contact with the Lower Palaeozoic rocks and the Leinster batholith and by Lower Palaeozoic Rocks to the north. The oldest Carboniferous rocks in Co. Dublin are argillaceous bioclastic limestones and shales. Younger Carboniferous rocks overlying these include poorly bedded limestone. The most extensive Carboniferous bedrock rock type, commonly known as the Calp, covers most of the central zone and some of the northern parts. It consists of laminated argillaceous calcilutites, calcareous shale and thinly bedded locally cherty limestone interbedded with black shale. These rocks were mainly deposited in warm shallow marine environments.

3.2 Geotechnical Profile

The geotechnical units (defined according to their geotechnical properties) come from the geological units (defined according to their geological age) that are characterised in the GDR. In some cases, a geological unit may be divided into two geotechnical units (a clayey one and a sandy one, or one according to depth), or different geological units may be combined into one geotechnical unit if it is considered that their geotechnical behaviour will be similar. Table 3-1 summarises the geotechnical units defined based on the GDR.

Table 3-1: Geotechnical Units

Granular / Cohesive units	Bedrock
Made Ground for MetroLink (Qx-ML).	Argillaceous Limestone (CLU), belonging to the Lucan Formation.
Made Ground at Green Line (Qx-GL).	Calcareous Shale Limestone (CTO), belonging to the Tober Colleen Formation.
Alluvial and Fluvioglacial sands and gravels (QAGwd & QAGlr).	Micritic Limestone (CWA), belonging to the Waulsortian Formation.
Pre-Glacial Sands & Gravels	Argillaceous Bioclastic Limestone (CML), belonging to the Malahide Formation.
Brown Boulder Clay (QBR<10m).	Upper Weathered rock (weathered part of bedrock for all types of rocks that is located at the contact with soils)
Brown Boulder Clay - QBR<10m and >10m.	
Black Boulder Clay - QBL<10m and >10m	
Base of Drift Deposits (BoD)	

To define the stratigraphy of the MetroLink alignment, and referring to all the geotechnical information available, the most representative boreholes from the original Old Metro North (OMN) ground investigation, supplemented by three Additional Ground Investigation (AGI) phases of this Preliminary Design have been selected. The analysis of this information is presented in table 5.1.

4. Subsidence Damage Assessment Methodology

4.1 Overview

The ground movement prediction and building damage assessment methodology adopted is based on the approach adopted by other notable UK and Irish tunnel projects, including the Channel Tunnel Rail Link (CTRL), Dublin Port Tunnel, Crossrail, and High Speed 2. The assessment of the effects of ground movements and potential impacts on existing buildings will be carried out in three phases, with Phase 1 and the initial analysis for Phase 2 (termed as Phase 2a) undertaken as part of the Preliminary Design. The detailed designer of the Design & Build (D&B) Contractor will then review and refine the Phase 2a assessment (as part of their Phase 2b assessment) and also undertake the Phase 3 assessment. The three phases are described below and are also illustrated by the accompanying flowcharts (Figures 4-1 and 4-2):

- **Phase 1** – the assessment of the greenfield settlement contours using generic ground parameters and the identification of buildings that are
    - **a)** enclosed by the 10mm contour or with a ground settlement slope > 1:500 and
    - **b)** those buildings enclosed by the 1mm contour subject to 'special' considerations.
- **Phase 2** – all the buildings identified in Phase 1 are assessed using the greenfield ground movement profile making credible foundation assumptions and are classified into Damage Categories 0 – 5; those buildings placed in Damage Category 3 or above, and those subject to 'special' considerations (see below) are carried through to Phase 3.
- **Phase 3** – each identified building is considered individually to determine its behaviour using detailed information and assessment methods; this may include a refined ground model, detailed structural surveys, refined construction methodology and use of sophisticated soil-structure interaction analysis such as finite element analysis.

In the context of building damage assessment, 'special' considerations refer to buildings (hereafter referred as 'special' buildings) in proximity of the excavation, with deep basements, or those identified as designated Protected Structures, or sensitive buildings as defined below:

- **Case A:** it is on shallow foundation and is within a distance from a retained cutting, shaft, or box equal to the excavated depth of superficial deposits or 50% of the total excavation depth, whichever is the greater. In this context, superficial deposits are taken to be soils above the rockhead level.
- **Case B:** it has a foundation level deeper than 4m, or (in the case of a bored tunnel) greater than 20% of the depth to tunnel axis.
- **Case C:** it is a Protected Structure
- **Case D:** any 'prominent' or 'sensitive' buildings that might need further assessment to determine whether any protective works required.

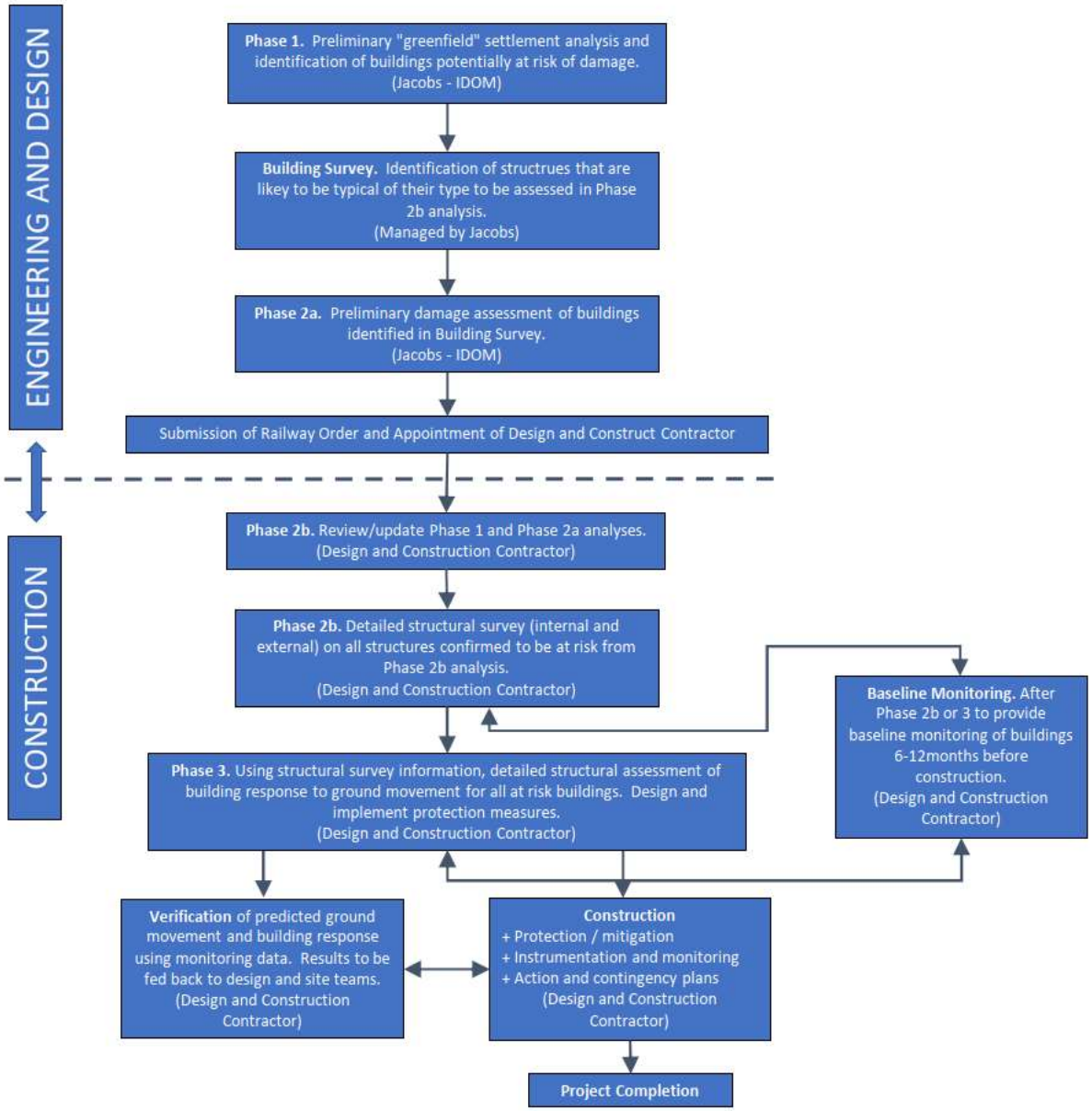


Figure 4-1: Building Settlement Damage Assessment Flow Chart Through The Project Life Cycle

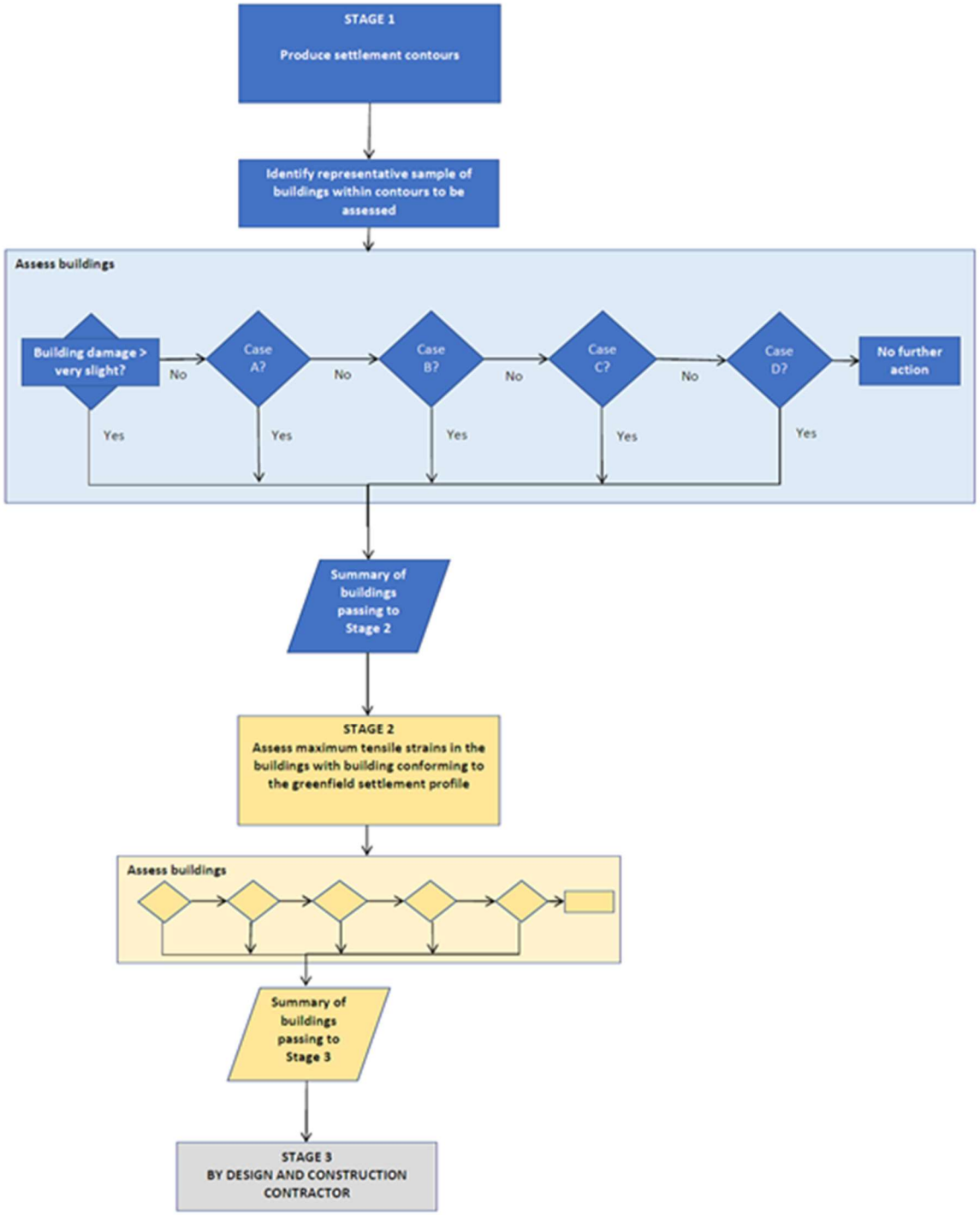


Figure 4-2: Settlement Assessment Flowchart With Building Categorisation Detail (Preliminary Design Phase in Blue)

4.2 Phase 1 – Generic Assessment Based on Greenfield Settlement Contours

4.2.1 General

Phase 1 involves the assessment of the greenfield settlement contours induced by the tunnelling and station boxes/retained walls construction works using ground parameters derived from published data and ground investigations undertaken. This is followed by the identification of buildings that are

a) within the 10mm contour or with a ground settlement slope > 1:500

b) 'special' buildings within the 1mm contour.

The Phase 1 settlement assessment for tunnelling has been undertaken using the Volume Loss methodology as aoutlined in CIRA PR 30. This is an empirical method based on the percentage of tunnel volume excavated that is over and above that required for the tunnel itself. The calculation of the resultant settlement trough requires the derivation of a number of ground factors which are described in section 4.2.2. to 4.2.4.

Settlement assessments for retaining wall construction and bulk excavation associated with the station box and retaining walls have been undertaken based on the case history data documented in CIRIA Report C760 "Embedded retaining walls – guidance for economic design" [Ref. 4] which are described in section 4.2.5.

4.2.2 Settlement Trough Due to Tunnelling

The induced settlement profile orthogonal to the tunnel alignment is derived using the semi-empirical method that was originally proposed by Peck (1969) [Ref. 5], and subsequently updated by O'Reilly and New (1982) [Ref. 6] and others. This method assumes that the shape of the settlement trough above a single tunnel follows a Gaussian (bell-shaped) distribution (see Figure 4-3), and the volume of the settlement trough is assumed to be equal to the total volume of lost ground during tunnelling. This method is based on case history data and previous experience of TBM tunnelling.

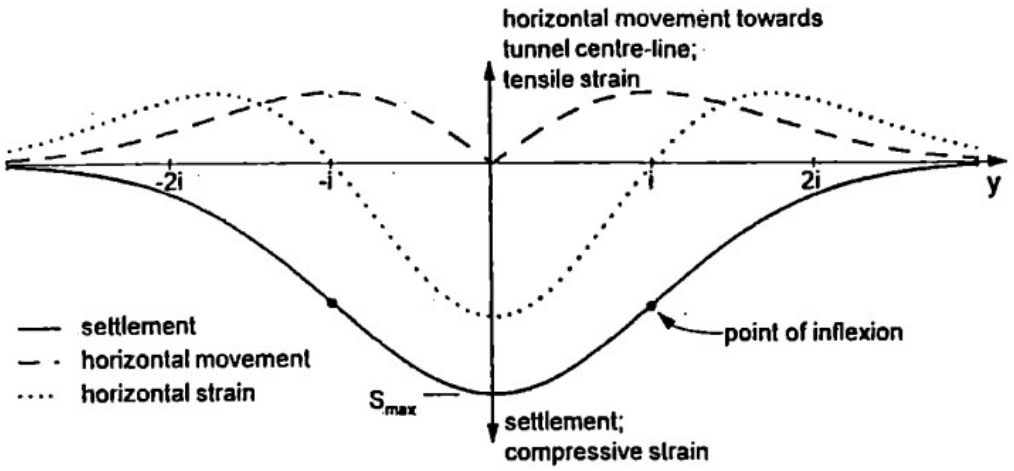


Figure 4-3: Transverse Settlement Trough Due to Tunnelling (After Mair, Taylor & Burland, 1996)

The settlement trough immediately after a tunnel has been constructed is described by a Gaussian distribution curve (see Figure 4-3) as

$$S_V = S_{max} \exp\left(\frac{-y^2}{2i^2}\right) \qquad [1]$$

$$i = Kz_0 \quad [2]$$

where S_v is settlement

S_{max} is the maximum settlement on the tunnel centre line

y is the horizontal distance from the centre line

i is the horizontal distance from the tunnel centre line to the point of inflexion on the settlement trough

K is the trough width parameter depending on the ground type i.e. clay or sand

z_o is the depth of tunnel axis below ground level.

and the volume of the settlement trough per metre length of tunnel (V_s) is evaluated as

$$V_s = \sqrt{2\pi}\, i\, S_{max} \quad [3]$$

4.2.3 Determination of Trough Width Parameter (K)

To select K values, two principal authors and other previous projects were consulted. The ranges of recommended K values are 0.2 to 0.3 for sands above the groundwater table, 0.4 to 0.7 for hard to soft clays (O'Reilly and New, 1982) [Ref. 6], and 0.2 to 0.6 for sands below the groundwater level, depending on the ratio of tunnel depth to tunnel diameter (Peck, 1969) [Ref. 5]. Studies that were reviewed suggest various K and V_s values for Dublin projects and others are presented in Table 4-1 below (Note: V_s is expressed as a percentage of the volume of the tunnel in this table which is equivalent to V_l used later by this document).

Table 4-1: Reference Values for K and V_s From Different Projects

Values of K and Vs	K		Vs(%)	
Considered IDOM/JACOBS	0,500	Boulder clay /QTR	0,500	Section completely in rock or ground with Hb/D>2
	0,800	BedRock	0,750	Section in Mixed face or 2>Hb/D>1.5
			1,000	Section with Hb/D<1.5
Document Evaluation of Risk Assesment	0,415	Averaged	0,690	Averaged
Paper Findlater's Church-J.Murphy.	0,400		0,760	Taken from Dublin Port
Dublin Port	0.47-0.51	Boulder clay	0.21-0.64	(1.66 locally as an exception)
Mair and Taylor(1997)	0.4-0.6	Clays	1-2	Open face tunnels London Clay
	0.25-0.45	Gravels&sands	0.5-2	Closed face tunnel, EPB, slurry shield
Proof of evidence. Professor John Burland	0.3	Fluvio glacial deposits	1,500	Mixed Face fluvio glacial deposits
	0.4	Limestone bedrock	0,600	Glacial Till
	0.6	Glacial Till	0,200	Limestone bedrock

Based on this information, the following values have been adopted for the MetroLink scheme depending on the geotechnical unit in which the tunnel face is located:

- Boulder Clay and Transition layer: K = 0.5
- Granular material: K = 0.3
- Bedrock: K = 0.4

In the case of mixed strata:

- if the tunnel is wholly in rock and there is at least half a tunnel diameter of rock cover above the crown, then K = 0.4
- otherwise, K depends on the predominant type of the ground above, K=0.3 if the cover is predominately granular, and K=0.5 if the cover is predominately cohesive.

4.2.4 Selection of Volume Loss Parameters (V_l)

Volume loss V_l is usually expressed as a percentage of the volume of the tunnel and will vary depending on the strata and is related to V_s by the following equation:

$$V_l = V_s / \frac{\pi D^2}{4} \qquad [4]$$

Where D is the tunnel diameter.

It can be estimated from other project references based on actual cases of urban tunnels constructed by TBM and other methods. The values of ground loss achieved in some of the past projects are presented in Table 4-2.

Table 4-2: Monitored Volume Loss From Recent Tunnelling Projects

Project names		Excavation Diameter (ft)	Excavation Completion	Excavation Method	Geologic Conditions	Typical Ground Losses (%)	References
Sao Paulo Metro Line 4 – Lot 1, Sao Paulo, Brazil		31.2	2009	EPBM	Three different geologic formations: soil derived from the alteration of gneiss, interbedded high to medium plasticity clay and sandy clay with gravel, and interbedded medium stiff to hard clay with fine to coarse sands	< 0.4	Pellegrini and Perruzza, 2009
Barcelona Metro Line 9, Barcelona, Spain[1]	Mas Blau to San Cosme Segment	30.8	2008	EBPM	Submerged fine silty sands and clayey silts	0.4 to 0.8	Mignini et al., 2008
	Segment IV-B (San Adria)	39.2	2007	EPBM	Sands, clay, and silts overlying gravels with sands	0.7 to 1.0	Della Valle, 2007
	Segment IV-C (Trajana)	39.2	2007	EPBM	Mixed face of silts and sands or gravels in a sandy clay matrix overlying highly to completely weathered granodiorite	0.2 to 0.6	Della Valle, 2007
	Fira to Park Logistic Segment	30.8	2006	EPBM	Silty sands with sandy silts, silts and silty clays	0.3 to 0.4	Orfila et al., 2007, Della Valle, 2007
Madrid South Bypass M-30 Tunnels, Madrid, Spain[1]		50.0	2007	EPBM	Mixed face of sandy clay overlying hard clay with gypsum	0.1 to 0.4	Universidade da Coruña, 2008. Fernandez, 2005
MTA Gold Line Eastside Extension, LA, USA[2]		21.4 (twin tunnels)	2007	EPBM	Mix of stiff to hard silt, lean clay, sandy clay, and loose to very dense sand and gravel, both above and below groundwater	< 0.3	Choueiry et al., 2007
Channel Tunnel Rail Link, London, UK[1]		26.7 (twin tunnels)	2004	EPBM	London clay: Stiff to hard clay	0.3 to 0.8	Bowers et al., 2005; Mair and Borghi, 2008.
					Fine and medium silty sand	0.3 to 0.8	
Docklands Light Railway Lewisham Extension, London, UK[1]		19.2 (twin tunnels)	1998?	Slurry TBM	Stiff to hard clays with gravels	0.7 to 1.0	Sugiyama et al., 1999
					Mixed face of stiff to hard clays and silty fine dense sand	0.5 to 0.9	

(1) Achieved ground losses in combination with careful control of bentonite injection around TBM and tail-skin grouting. Higher ground losses were reported for locations where ground movement control measures were not implemented or were or poorly implemented, or along the tunnel excavation learning curve.

(2) Ground loss values back-calculated from the settlements reported in the paper.

At this Preliminary Design stage, the following values of V_l have been adopted conservatively for the Phase 1 assessment (refer to Key Assumption Register in Appendix E):

- Superficial material (clay or granular material): $V_l = 1.5\%$
- Rock strata: $V_l = 0.75\%$

In the case of a mixed strata:

- If the tunnel is wholly in rock and there is at least half-a-tunnel diameter rock cover above the crown, then $V_l = 0.75\%$
- Else $V_l = 1.5\%$.

For the non-TBM construction, the volume loss values have been taken as 50% more than that of the corresponding TBM volume loss values.

These are conservative values for the ground conditions predicted to be encountered along the route and it is possible the actual values could be close to half to two-thirds of the above values. Nevertheless, these values have been adopted for the initial Phase 2a assessment to verify whether any buildings fall under Building Damage Category 3 under such conservative assumptions. It is likely that the D&B Contractor for the project will adopt lower volume loss values for their Phase 2b assessment and therefore the initial Phase 2a building damage categories reported in this report are likely to improve during the Phase 2b assessment.

For the refined Phase 2a assessment carried out and described by this report, moderatly conservative volume loss values have been taken as two-thirds of the above values and the results reported as detailed in Section 5.2.

4.2.5 Ground Movement Due to Station Boxes and Retaining Walls

Cut & cover station boxes, cut and cover tunnels, and retained cuttings along the alignment will be constructed using either diaphragm walling or secant piling methods. Ground movements will occur both due to the installation of the walls or piles, and then due to the subsequent bulk excavation from within these retaining wall structures. The magnitude of the ground movements will be dependent on the type of ground, the ground water conditions and the method of construction (top-down or bottom-up), and the stiffness of the wall/propping system. Considering that the construction methodology for the station boxes and the retained cuttings will be further refined as the design progresses beyond the Preliminary Design stage, a conservative empirical approach has been adopted to predict greenfield settlements in accordance with the guidance (based on case history data) provided by CIRIA Report C760.

The following key construction methodology assumptions have formed the basis of the ground movement impact assessment undertaken and described by this document (refer to Key Assumptions Register in Appendix E):

- all the station box excavations will adopt a top-down method of construction with retaining walls supported using high level props during construction to minimise ground movement effects.
- perimeter walls for the main station boxes will be constructed using diaphragm walling.
- perimeter walls for the sub-excavations adjacent to the main station boxes will be constructed using secant pile walls.
- portals, shafts and retained cuttings will be constructed using secant pile walls.
- dewatering of the ground outside of the site boundary is controlled during construction to prevent any adverse impacts.

The CIRIA report provides normalised curves (normalised by the depth of excavation) for assessing both settlements and horizontal movements due to wall construction and bulk excavation associated with station box and retaining wall constructions in superficial strata. The extract of the normalised curves from the CIRIA report are included at the end of this section as Figure 4.6 for ease of reference.

For assessing the settlements and horizontal movements due to the wall construction, the following normalised curves have been used:

- Figure 6.8 of CIRIA 760 [Ref. 4] for secant pile wall construction (shown as Figure 4.7a);
- Figure 6.9 of CIRIA 760 [Ref. 4] for diaphragm wall construction (shown as Figure 4.7b).

For assessing the settlements and horizontal movements due to the bulk excavation associated with station box and retaining wall constructions, the following normalised curves have been used:

- Figure 6.15 of CIRIA 760 [Ref. 4] for excavation in cohesive strata (shown as Figure 4.7c); the curves corresponding to ‘high stiffness’ have been used considering that the station box will be constructed using a top-down method and retaining walls will be supported using high level props during construction.
- Figure 6.16 of CIRIA 760 [Ref. 4] for excavation in granular strata (shown as Figure 4.7d); curves are only available for assessing settlement with ‘low stiffness’ walls in the CIRIA report and no curves are available for assessing horizontal movements; the effect of horizontal movements have been ignored for cases with granular strata (Tara, O’Connell Street and Mater stations are classified as in granular strata). This is compensated for by adopting the settlement curves corresponding to a ‘low stiffness’ case which is conservative for the actual situation, i.e., ‘high stiffness’ case in actual situation as mentioned above.

It should be noted that the above curves are based on excavation works within superficial material and therefore they are considered to be conservative for the section of the excavation works within the rock strata. When adopting the CIRIA 760 curves, the effective depth of excavation has therefore been taken as:

- For the wall construction, the effective depth of excavation is the depth of wall within the superficial strata, plus 50% of the excavation within the rock strata.

- For the bulk excavation, the effective depth of excavation is the depth of excavation within the superficial strata, plus 20% of the excavation within the rock strata.

Appropriate ground movement curves derived from CIRIA 760 [Ref. 4] have been input into the settlement software XDisp to determine settlement contours due to wall installation and subsequent bulk excavation within the perimeter retaining walls. For the Phase 1 assessment, only the settlement (vertical movements) predictions have been used, with the horizontal movements utilised for the Phase 2a assessment.

Dewatering outside the site boundary will be controlled so that it is maintained within its natural fluctuation during the construction phase and therefore no additional settlement effects due to dewatering are allowed for. In the permanent condition, retaining structures will be designed as effectively watertight and therefore no significant dewatering of the surrounding ground will occur.

4.2.6 Preparation of Settlement Contour Drawings

The software package XDisp has been used to calculate settlement contours. Working on a 2m x 2m grid with overburden depths and ground conditions imported from the longitudinal sections, the software produces a contour data set that is subsequently imported into Civil 3D to generate the settlement contour drawings. These settlement contour drawings are provided in Appendix C.

Once the contour drawings have been produced, it is possible to identify all buildings enclosed by the 10mm contour or with a ground settlement slope > 1:500; and all 'special' buildings (refer Section 4.1) enclosed by the 1mm contour.

The output from the Phase 1 assessment is:

a) a table showing the volume loss (V_l) and trough width coefficient (K) values adopted along the alignment

b) settlement contour drawings identifying all buildings enclosed by the 10mm contour or with a ground settlement slope > 1:500

c) identification of 'special' buildings enclosed by the 1mm contour

The results of the Phase 1 assessment are provided by Section 5 of this report.

4.3 Phase 2 Assessment

4.3.1 General

The Phase 2 assessment is split into two sub-phases, namely Phase 2a and Phase 2b as follows:

a) Phase 2a is undertaken as part of the Preliminary Design. This sub-phase initially adopts the same conservative assumptions used to predict the Phase 1 greenfield ground movements; refined assumptions are sometimes made to assess the sensitivity of the initial assessment results.

b) Phase 2b is a confirmatory/refined analysis undertaken by the detailed designer of the D&B Contractor. This sub-phase usually adopts tighter volume loss parameters and utilises a more refined construction methodology since the D&B contractor will now be progressing the development of the detail design and finalising his construction methodology and planning. .

4.3.2 Building Damage Categorisation

Classification of building damage has traditionally been divided into three categories:

- Architectural damage affects the appearance of structures and is usually related to cracks or separations in panel walls, floors, and finish. Cracks in plaster greater than 0.1 mm wide and cracks in masonry or rough concrete walls greater than 1 mm wide are representative of a threshold, where damage is noticed and reported by building occupants (O'Rourke et al., 1976 [Ref. 7]; Burland et al., 1977 [Ref. 8]).

- Functional damage affects the use of the structure, and is exemplified by jammed doors and windows, extensively cracked, and falling plaster, tilting of walls and floors, and other damages that would require non-structural repair to return the building to its full-serviceable capacity.
- Structural damage affects the stability of the structure, usually related to cracks or distortions in primary support elements such as beams, columns, and load bearing walls.

These classifications are quite general and without clearly defined limits. As a result, there may be considerable overlap of the categories depending on the type and use of the structure considered. Burland et al., 1977 [Ref. 8] presents a classification of visible damage based on the works of Jennings and Kerrich (1962) [Ref. 9], the UK's National Coal Board (1975) [Ref. 10], and MacLeod and Littlejohn (1974) [Ref. 11]. The classification system shown in Table 4-3 is based on the ease of repairing the visible damages, and thus provides a defined framework for the evaluation of damage.

Table 4-3: Classification of Building damages, Burland et al (1977)

Damage Category	Description of Typical Damage	Approximate Crack Width (mm)
Negligible	Hairline cracks.	< 0.1
Very slight	Fine cracks that can easily be treated during normal decoration	< 1.0
Slight	Cracks easily filled. Redecorating probably required.	< 5
Moderate	The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced.	5-15 or number of cracks >3
Severe	Extensive repair work involving removing bricks and replacing sections of walls, especially over doors and windows.	15-25 but also depends on number of cracks
Very severe	This requires a major repair job involving partial or complete rebuilding.	Usually >25 but also depends on number of cracks

The chart below shows the Burland damage classification where the deformations are measured using two different criteria: Boscardin-Cording (Boscarding and Cording, 1989 [Ref. 12]) and Rankin (Rankin, 1988 [Ref. 13]). Boscardin-Cording's criteria considers a limiting tensile strain (within the building) approach whilst Rankin's criteria evaluate the ground settlements and distortions. The building risk categories shown in Table 4-4 are used to define the degree of building damage related to the Risk Category.

Table 4-4: Building Risk Categories (Boscardin and Cording with Rankin Criteria)

Building and Structure Damage Classification (after Burland et al (1977) and Boscarding and Cording (1989))					Approximately Equivalent Ground Settlements and Slopes (after Rankin 1988)	
Risk Category	Degree of Damage	Description of Typical Damage and Likely Forms of Repair for Typical Masonry Buildings	Approx. Crack Width (mm)	Limiting Max Tensile Strain (%)	Max Slope of Ground	Maximum Settlement of Building (mm)
0	Negligible	Hairline cracks	<0.1	Less than 0.05		
1	Very Slight	Fine cracks easily treated during normal redecoration. Perhaps isolated slight fracture in building	0.1 to 1	0.05 to 0.075	Less than 1:500	Less than 10

Building and Structure Damage Classification (after Burland et al (1977) and Boscarding and Cording (1989))					Approximately Equivalent Ground Settlements and Slopes (after Rankin 1988)	
Risk Category	**Degree of Damage**	**Description of Typical Damage and Likely Forms of Repair for Typical Masonry Buildings**	**Approx. Crack Width (mm)**	**Limiting Max Tensile Strain (%)**	**Max Slope of Ground**	**Maximum Settlement of Building (mm)**
		Cracks in exterior brickwork visible upon close inspection				
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible some re-pointing may be required for weather tightness. Doors and windows may stick slightly	1 to 5	0.075 to 0.15	1:500 to 1:200	10 to 50
3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can me masked by suitable linings. Re-pointing and possibly replacement of a small amount of extent brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather tightness often impaired	5 to 15 or a number of cracks greater than 3	0.15 to 0.3	1:200 to 1:50	50 to 75
4	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted.	15 to 25 but also depends on number of cracks	Greater than 0.3	1:200 to 1:50	Greater than 75
5	Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require shoring. Windows broken by distortion Danger of instability	Greater than 25 but also depends on number of cracks	Greater than 0.3	Greater than 1:50	Greater than 75

This can also be represented graphically (see Figure 4-4) to classify the damage categories in accordance with the maximum tensile strain on the horizontal axis and building deflection on the vertical axis. The example shown by Figure 4-4 is developed for the case of buildings with height equal to its length. Different graphs are used for different building height over length ratios.

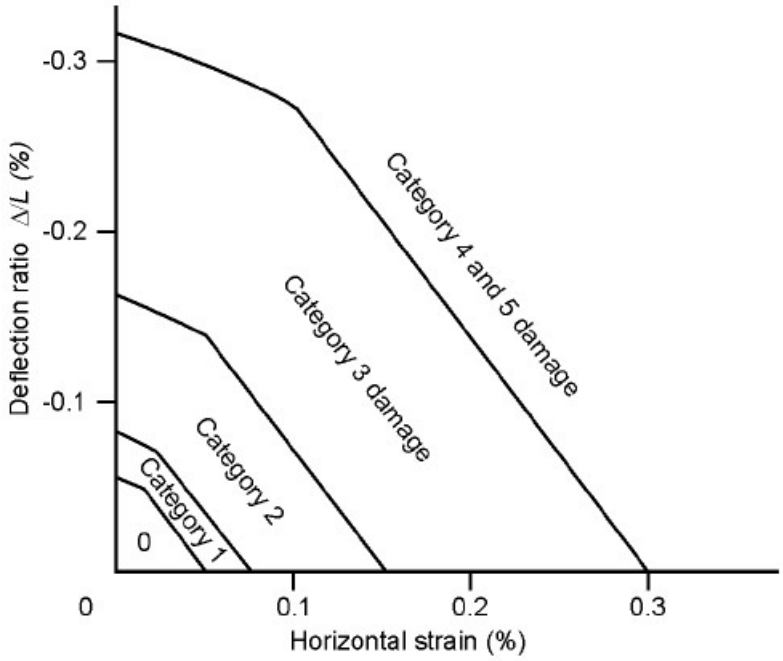


Figure 4-4: Relationship Between Damage Category to Deflection Ratio and Horizontal Tensile Strain (Burland 1995)

4.3.3 Preliminary Design Stage Building Surveys

The majority of the buildings/structures under which the MetroLink tunnels pass will respond in a similar way to tunnelling induced ground movement. During the Preliminary Design, preliminary surveys were commissioned on selected representative buildings, which were identified as might be impacted by the MetroLink works. Based on the ground movement impact assessment work carried out and presented in this report, surveys will be commissioned for all buildings that could be impacted by the MetroLink works. These will be commissioned and carried out as part of the detailed design. The level of detail of each survey will be proportional to the location and sensitivity of each building/structure and the predicted damage category of each building/structure.

Section 4.6 describes the identification process adopted for selecting the 'representative' buildings which have been subsequently surveyed as a part of the Preliminary Design works.

4.3.4 Phase 2a Building Response

The methodology to determine building response to greenfield ground movements is based on the determination of the limiting tensile strain induced into the building as it flexes to the profile of the settlement trough. Buildings are assessed according to this value of limiting tensile strain. Those in Category 3 or above, as per Table 4-4 (damage category Moderate or above) and 'special' buildings (refer to Section 4.1) will progress through to Phase 3 assessments.

The methodology to estimate the limiting tensile strain ε_{lim} comprises the following six steps. It is the same for buildings above the tunnel or those potentially impacted by station box or retaining wall construction:

1. Determination of the inflection point of the settlement curve.
2. Relative positioning of the building.
3. Determination of the maximum bending strain (ε_b) and diagonal strain (ε_d) considering sagging and hogging.
4. Determination of the horizontal strain $\varepsilon_{h.}$
5. Combination of the horizontal strain and the tensile strain, determining the limiting tensile strain $\varepsilon_{lim.}$

6. Determination of the damage category.

A typical case of a building affected by a single tunnel settlement trough is shown in Figure 4-5. The height H is taken as the height from the foundation level to the eaves of the building. It is assumed that a building can be considered separately either side of the settlement profile point of inflexion. The length of building is not considered beyond the practical limit of the settlement trough, which is 2.5i for the case of single tunnel. When calculating the building strain, building span length is required and is defined as the length of building in a hogging or sagging zone (L_h or L_s in Figure 4-5) and is limited by the point of inflexion or the extent of the settlement trough.

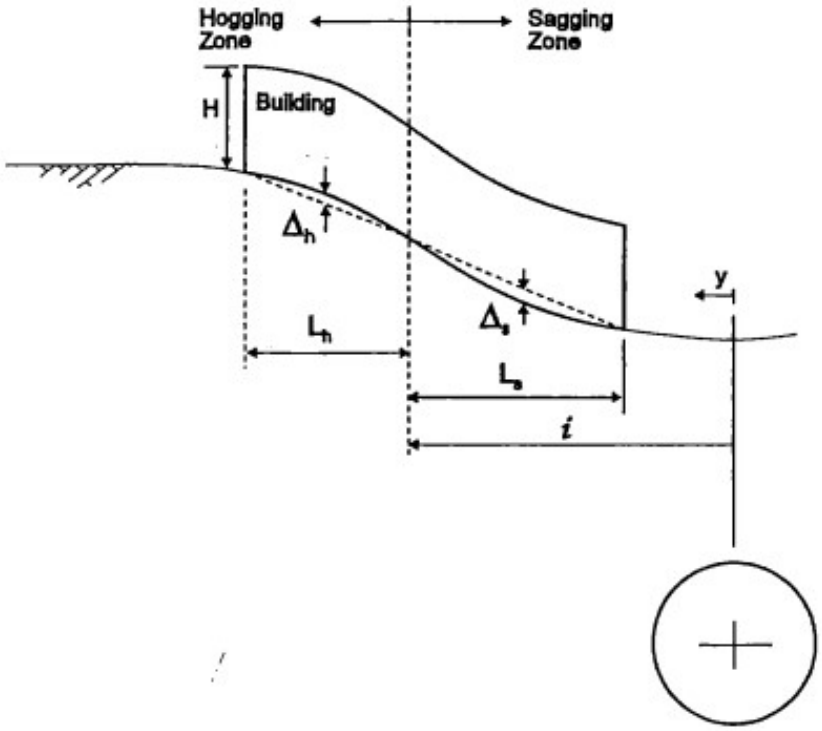


Figure 4-5: Building Deformation (After Mair, Taylor & Burland, 1996)

Ground movements generate tensile strains in buildings which can lead to cracking and damage. By treating the building as an idealised beam with span L and height H deforming under a central point load to give a maximum deflection Δ, the maximum bending strain (εb) and diagonal strain (εd) can be obtained from the following equations:

$$\frac{\Delta}{L} = \left\{\frac{L}{12t} + \frac{3I\,E}{2tLH\,G}\right\}\varepsilon_b \qquad [5]$$

$$\frac{\Delta}{L} = \left\{1 + \frac{HL^2G}{18IE}\right\}\varepsilon_d \qquad [6]$$

Where H is the height of the building

L is the length of the building (but limited by any point of inflexion or extent of settlement trough);

E and G are respectively Young's Modulus and shear modulus of the building assumed to be acting as a beam); although masonry is not an isotropic material, the ration E/G is taken as 2.6 which is consistent with an isotropic Poisson's ratio of 0.3

I is the second moment of area of the equivalent beam ($H^3/12$ in the sagging zone assuming the neutral axis remains in the middle of the 'beam'; and $H^3/3$ in the hogging zone considering the restraining effect of the foundation which would lower the neutral axis to coincide with the lower extreme fibre of the 'beam')

t is the furthest distance from the neutral axis to the edge of the beam (H/2 in the sagging zone and H in the hogging zone).

These calculations conservatively assume that the building follows the ground settlement trough at the foundation level. In the hogging zone, where the neutral axis is assumed to be at the bottom, all strains due to bending will be tensile. In the sagging zone, where the neutral axis is assumed to be at the centre of the building, bending will cause both compressive and tensile strains. For a given ratio Δ/L, the hogging mode is likely to be more damaging than the sagging mode.

Building damage can also result from horizontal tensile strain and therefore a prediction of horizontal movement is required. For the case of tunnelling induced ground movements, a conservative assumption is usually made (Mair et al. 1996) so that the resultant vectors of ground movement are directed towards the tunnel axis, allowing a simple assessment of horizontal movement as given by equation [7].

$$S_h = \frac{y}{z_0} S_v \qquad [7]$$

Where S_v is the vertical component of the ground movement

S_h is the horizontal component of the ground movement

The relation between the settlement trough, horizontal movements and horizontal strains occurring at ground level are shown in Figure 4-3. The horizontal ground strain ε_h is determined by differentiating equation [7] with respect to y. In the region i>y>-i, horizontal strains are compressive; at points of inflexion (y=+/-i), the horizontal strain is zero; for i<y<-i, the horizontal strains are tensile. The average horizontal strain across a section of building is more appropriate in the context of potential damage than local horizontal strains. Equations [1] to [7] can be used to calculate the horizontal movement at either end of a building span under consideration; the difference between these divided by the span length gives the average horizontal strain.

A similar principle is adopted to determine the average horizontal strains due to cut and cover tunnels, retained cuts and station box construction. The horizontal movement at either end of a building span under consideration is assessed using the process described in section 4.2.5 and the average horizontal strain determined.

The total average horizontal strain is then combined with either the bending or diagonal strain obtained from equations [5] and [6], and the maximum combined tensile strain is used in the assessment of potential building damage. The horizontal strain can be added directly to the bending strain to obtain the total bending strain (ε_{bt}) given by

$$\varepsilon_{bt} = \varepsilon_h + \varepsilon_b \qquad [8]$$

Similarly, diagonal (shear) strain and horizontal strain can be combined (utilising Mohr's circle of strain with Poisson's ration of 0.3) to obtain the total strain due to diagonal strain (ε_{dt}) given by

$$\varepsilon_{dt} = 0.35\varepsilon_h + \left[(0.65\varepsilon_h)^2 + \varepsilon_d^2\right]^{0.5} \qquad [9]$$

The maximum value of the combined tensile strain obtained from equations [8] and [9] is used in the assessment of potential building damage category as classified by Table 4-4.

The results of Phase 2a assessment are presented and discussed in Section 5 of this document.

4.4 Subsequent Phase 2b Assessments

All buildings that have been subject to a Phase 2a assessment will be reviewed and reassessed by the D&B Contractor. This Phase 2b assessment will use refined and updated parameters available to the D&B contractor as a result of him progressing the development of the detail design and finalising his construction methodology and planning.

The D&B contractor will benefit from being able to; precisely define and refine the construction methodology, select the most appropriate excavation and construction methodologies, and benefit from greater design maturity, thereby being in a position to confidently use less conservative assumptions to assess the impact of construction generated ground movements. It is therefore likely that the Phase 2b assessed damage category of buildings will improve upon the results of the Phase 2a assessment.

4.5 Phase 3 Assessment

All buildings that have been classified at the end of the Phase 2b assessment as Damage Category 3 (Moderate) or above (or where there exists any uncertainty after the Phase 2b assessment) will be the subject of a Phase 3 assessment by the D&B Contractor. Furthermore, all 'special' buildings (refer to Section 4.1), which have been the subject of a Phase 2a/2b assessment, but which do not qualify for further assessment (Damage Category 2 or below) will also be the subject of a Phase 3 assessment.

For the Phase 3 assessment, each building will be subject to detailed assessment on an individual basis. Both the strains developing within the building, and the applicability of the classification of risk categories will be reviewed in terms of their relevance for the buildings undergoing Phase 3 assessment. The purpose of the Phase 3 assessment is to ensure that any uncertainty or risk that might lead to damage is minimised.

A detailed survey will be carried out as part of the Phase 3 assessment to provide the necessary additional information to inform this detailed analysis of how the individual elements of the building would be affected by the predicted ground movements. The method and extent of the detailed analysis will be determined on a case-by-case basis and may include a more sophisticated semi-empirical or a detailed soil-structure interaction using finite element modelling methods. As part of this analysis, the detailed design and construction methodology, including the stiffness of the wall and propping system, together with the beneficial effects of the overall structural stiffness of the building will be taken account of. The overall structural stiffness of the building will limit the deformation of the building to the greenfield settlement profile and thus reduce the maximum tensile strains experienced by the building. It is therefore likely that the Phase 3 assessment will yield further improvement to the damage category determined by the Phase 2b assessment.

The ultimate output of the Phase 3 analysis will be to minimise risk and uncertainty and finalise any necessary protection works required to mitigate the impact of construction generated ground movements. This may include further refinement or modification by D&B Contractor of TBM drive parameters and control measures.

4.6 Building Survey

A review of the alignment has been undertaken to identify buildings that could be impacted by MetroLink sub-surface construction and would be considered typical of their type e.g., a typical 4-storey brick townhouse; a typical 2-storey terraced house etc. This review identified 219 typical buildings, hereafter referred as 'representative' buildings, for input into the damage assessment process. A survey also identified 'special' buildings as defined by section 4.1. The full list of 'representative' buildings and 'special' buildings is provided in Appendices B.1 and B.2.

Since building surveys were required to commence before the initial drafting of the settlement contours, a 30m wide tunnelling zone of influence was assumed either side of the running tunnel based on a 45-degree influence line from the tunnel axis (see Figure 4-6). This was assessed as the reasonable worst-case influence zone for the entire length of the tunnelling works. This has since been checked and verified to make sure that at no point would the influence zone extend further than 30m from the tunnel.

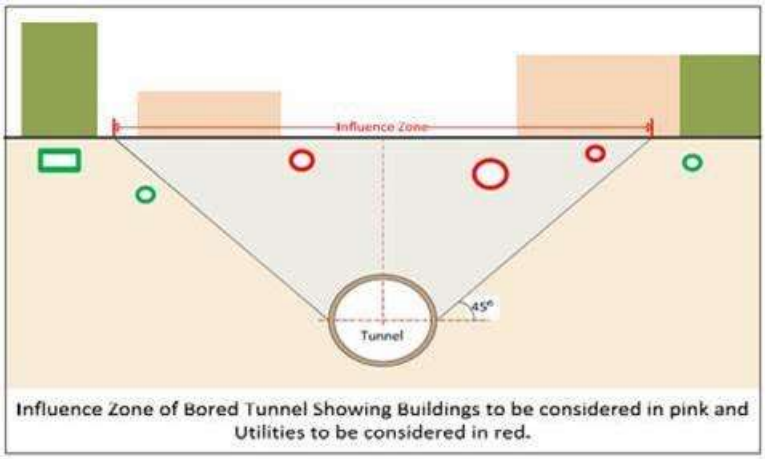


Figure 4-6 – Assumed Influence Zone of Bored tunnel

Each identified building has been the subject of an external survey and an internal survey where a need was identified. These survey sheets which include important building information such as form of construction and height etc. have been used to inform the building settlement impact assessment.

The main characteristics ascertained in the building surveys were:

- Description and current usage
- Position in relation to the tunnel alignment
- Number of floors
- Number of basements
- Type of foundation (shallow foundation or piles)
- Current condition
- Any other aspects pertaining to its foundation or vulnerability

4.7 Settlement Effects Due to Dewatering

The perimeter diaphragm walls forming the station boxes will provide effective water cut-off during station box construction and excavation, with any upward flow of groundwater (from below the station formation level) limited to negligible. If analysis identifies a risk that upward groundwater flows could be excessive, a ground water cut-off plug will be formed inside the perimeter walls just above the toe level of the perimeter wall.

No external dewatering (outside of the site boundaries) will be permitted during the construction of the station boxes, that increases the impact due to settlement on others, beyond the natural ground water fluctuation. Any settlement due to the short-term lowering of the water table outside of the station box will therefore be constrained to within the site boundaries. Similarly, no dewatering outside the cut and cover tunnel sections or other retained cuttings will be permitted that increases the impact due to settlement on others.

Figure 4.7: Extracts from CIRIA 760 [Ref. 4] (Normalised Ground Movement Curves)

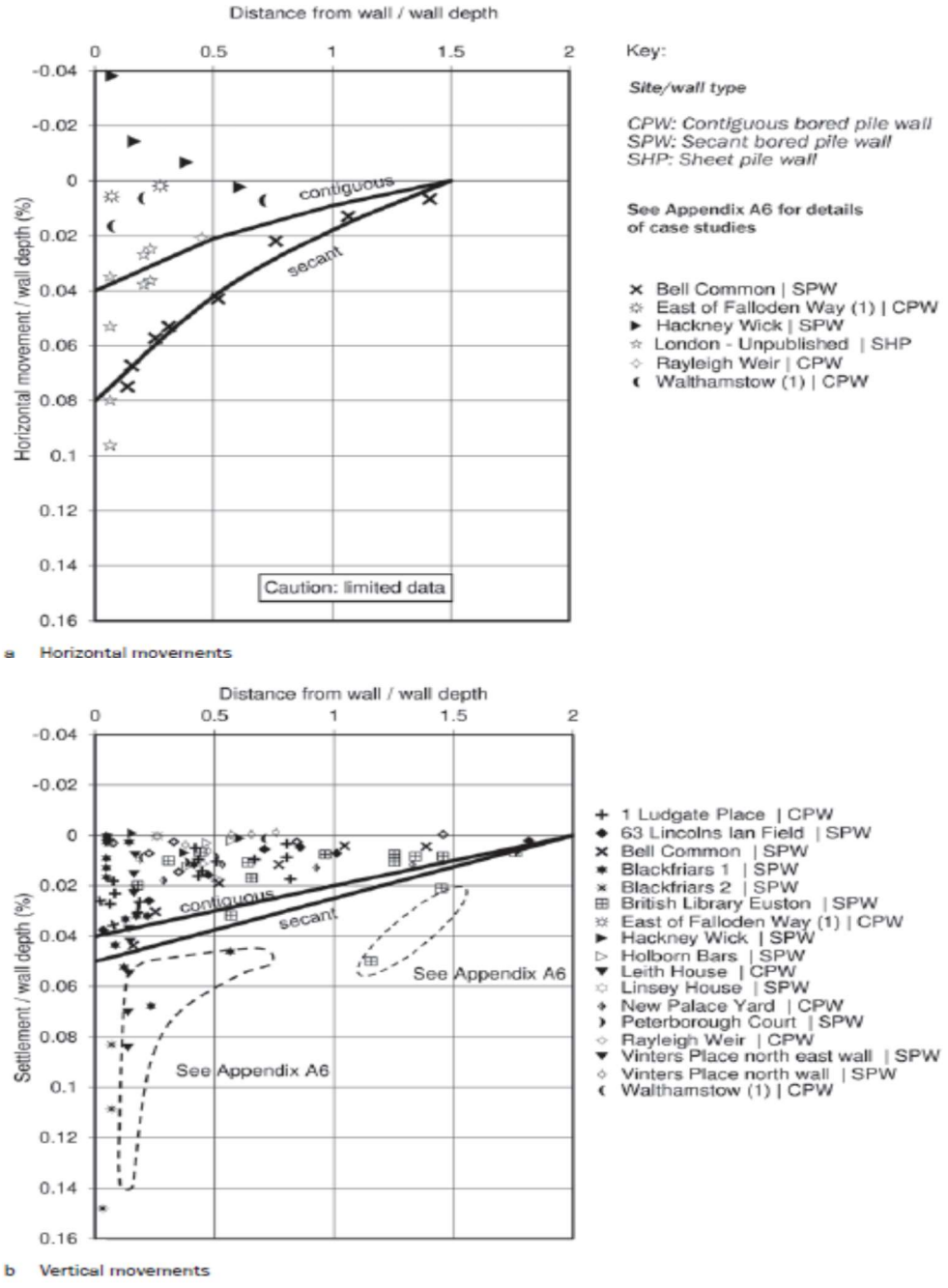


Figure 4.7a: Ground Movement curves – Secant Pile Wall Construction (cohesive strata)

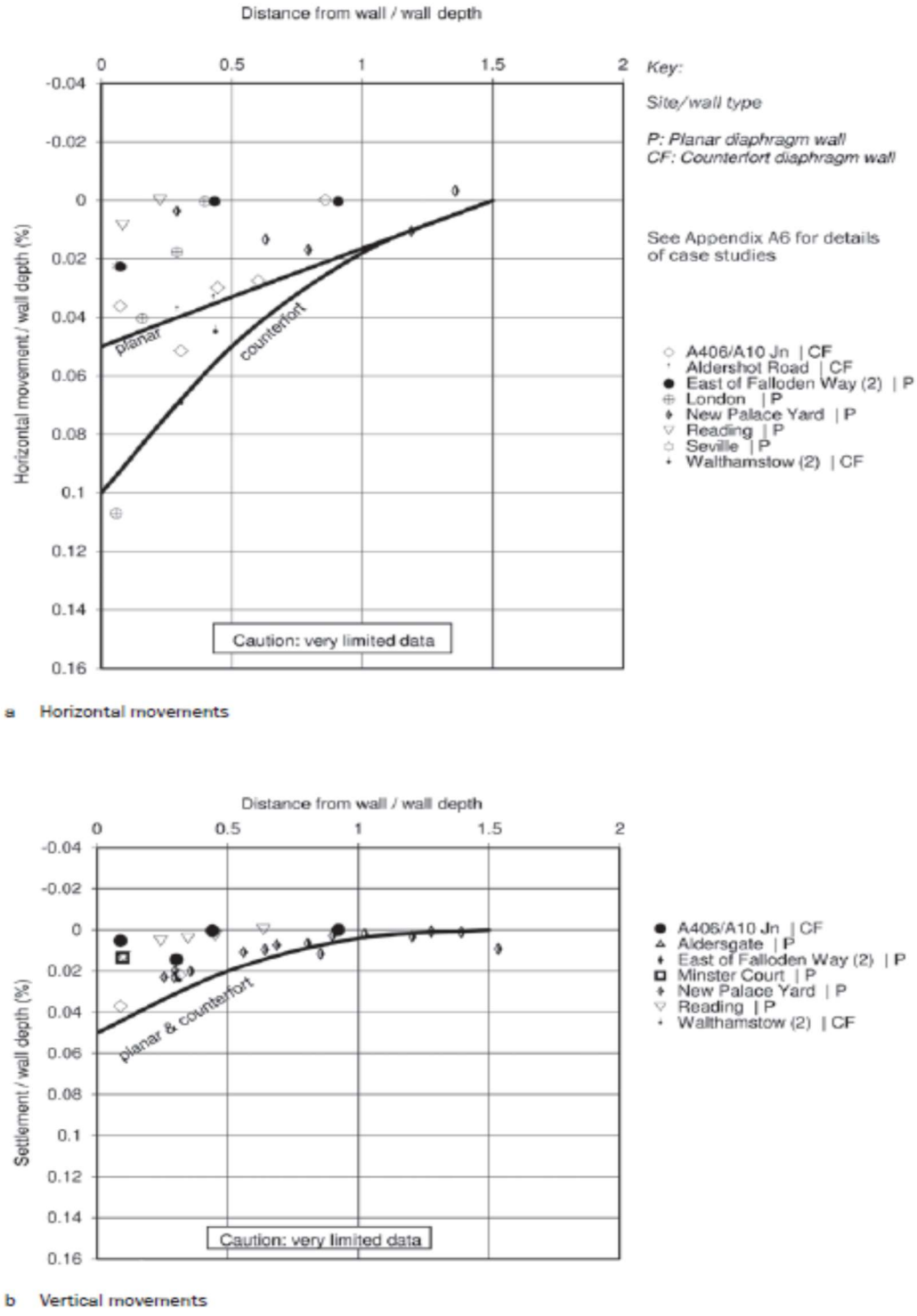


Figure 4.7b: Ground Movement Curves – Diaphragm Wall Construction (cohesive strata)

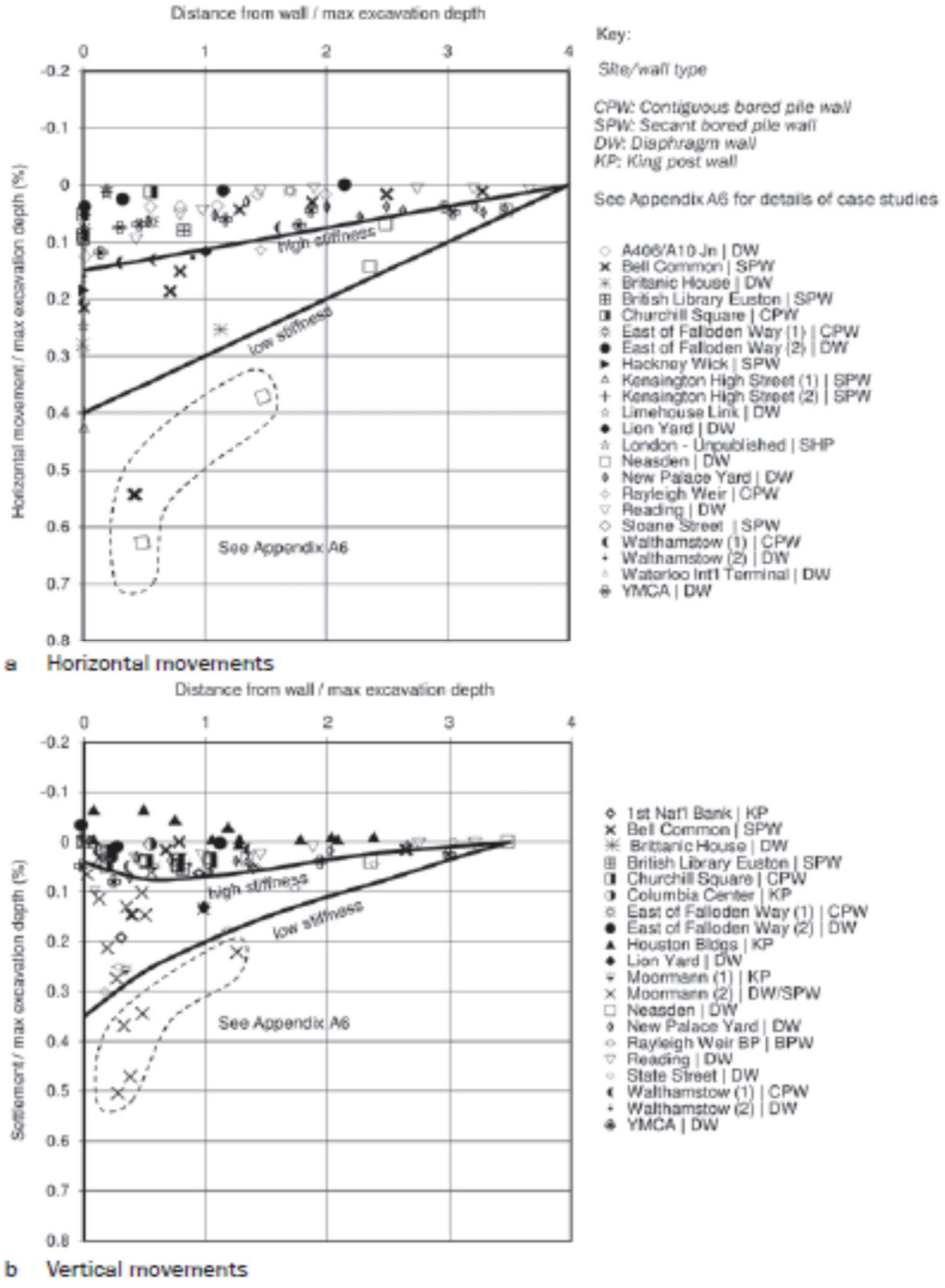


Figure 6.15 Ground surface movements due to excavation in front of wall embedded in stiff clay

Figure 4.7c: Ground Movement Curves – Bulk Excavation In Front of Wall (cohesive strata)

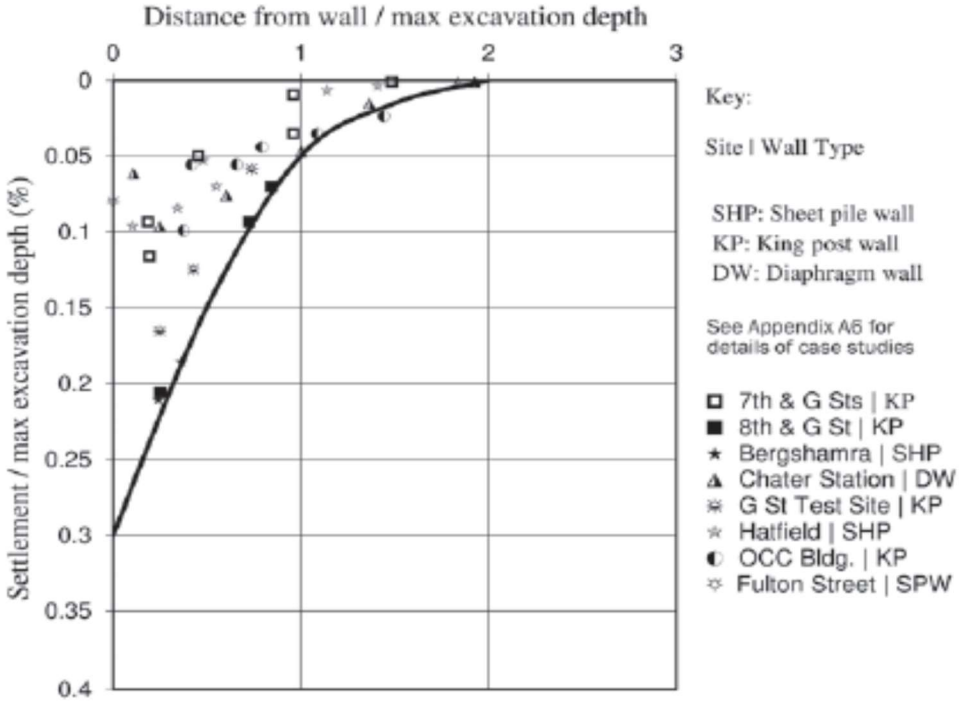


Figure 6.16 Ground surface settlement due to excavation in front of wall in sand

Figure A4.7d: Ground Movement Curves – Diaphragm Wall Construction (granular strata)

5. Assessment Results and Discussion

5.1 Phase 1 Building Assessment

The following parameters form the basis of the Phase 1 greenfield settlement assessment:

- Overall ground conditions – these are obtained from the geological long section (See EIAR Appendix A 20.4);
- Adopted Volume Loss (V_L) – for the tunnelling induced ground movements (refer to Section 4.2.4);
- Trough width parameters (K) – for the tunnelling induced ground movements (refer to Section 4.2.3).

This information is tabulated in Table 5.1. The greenfield settlement contour drawings are presented in Appendix C.

The Phase 1 assessment involves identification of buildings for Phase 2a assessment. All buildings enclosed by the 10mm contour boundary have been subject to Phase 2a assessment. Further, it has been checked and confirmed that

- the slope of the settlement trough outside the 10mm contour line is less than 1 in 500 and therefore no additional buildings are to be included for Phase 2a assessment based on this slope criteria.
- there are no additional buildings to be included for Phase 2a assessment due the criteria set out by Case-A referred in Section 4.1.

In addition to the above, all 'representative' buildings (Refer to Section 4.6) enclosed by the 1mm contour boundary have also been identified for Phase 2a assessment. Any 'representative' buildings located outside of the 1mm contour have not been subject to any further assessment - these details are also included in Table 5-2 for completeness.

Table 5-1: Details of Ground Conditions, V_L and K Values by Chainage

Start Chainage	End Chainage	Length (m)	Excavated Material	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Vs (%)	K
6100	6400	300	CMUP/Sands and Gravels/QBL	QBL (90%)	Qx (10%)				1.5	0.5
6400	6500	100	CMUP/Sands and Gravels	Sands and Gravels (20%)	QBL (70%)	Qx (10%)			1.5	0.5
6500	6640	140	CMUP/Sands and Gravels	Sands and Gravels (20%)	Fluvio-Glacial sands (20%)	QBL (50%)	Qx (10%)		1.5	0.5
6640	6800	160	CMUP/Sands and Gravels	Sands and Gravels (20%)	QBL (70%)	Qx (10%)			1.5	0.5
6800	6960	160	CWA/Sands and Gravels	Sand and Gravels (10%)	QBL (80%)	Qx (10%)			1.5	0.5
6960	7000	40	**CWA**	**CWA (50%)**	**Sands and Gravels (20%)**	**QBL (20%)**	**Qx (10%)**		**0.75**	**0.4**
7120	7190	70	**CWA**	**CWA (60%)**	**Sands and Gravels (20%)**	**QBL (10%)**	**Qx (10%)**		**0.75**	**0.4**
7190	7260	70	CTO	CTO (20%)	Fluvio-Glacial Sands (20%)	QBL (40%)	Qx (20%)		1.5	0.5
7260	7480	220	CTO/Sands and Gravels/QBL	QBL (90%)	Qx (10%)				1.5	0.5
7480	7730	250	CTO/QBL/Fluvio-Glacial sands	Fluvio-Glacial sands (20%)	QBL (70%)	Qx (10%)			1.5	0.5
7730	7820	90	QBL	QBL (90%)	Qx (10%)				1.5	0.5
7820	7950	130	QBL	QBL (70%)	Fluvio-Glacial Sands (20%)	Qx (10%)			1.5	0.5
7950	8000	50	CTO/Sands and Gravels	Sands and Gravels (20%)	QBL (70%)	Qx (10%)			1.5	0.5
8000	8080	80	CTO	CTO (10%)	Sands and Gravels (10%)	QBL (70%)	Qx (10%)		1.5	0.5
8080	8160	80	CTO/Sands and Gravels/QBL	QBL (90%)	Qx (10%)				1.5	0.5
8160	8400	240	QBL/Fluvio-Glacial sands	QBL (90%)	Qx (10%)				1.5	0.5
10400	10540	140	QBR/Sands and Gravels/CLU	QBR (90%)	Qx (10%)				1.5	0.5
10540	10720	180	CLU/Sands and Gravels	Sands and Gravels (20%)	QBR (60%)	Fluvio-Glacial Sands (10%)	Qx (10%)		1.5	0.5
10720	10980	260	CLU/Sands and Gravels	QBR (90%)	Qx (10%)				1.5	0.5
10980	11220	240	CLU/Sands and Gravels	QBR (80%)	Fluvio-Glacial Sands (10%)	Qx (10%)			1.5	0.5
11320	11440	120	CLU/Sands and Gravels/QBR	QBR (60%)	Fluvio-Glacial Sands (20%)	Qx (20%)			1.5	0.5
11440	11480	40	CLU/Sands and Gravels/QBR	QBR (90%)	Qx (10%)				1.5	0.5
11480	11600	120	CLU/Sands and Gravels/QBR	Fluvio-Glacial Sands (20%)	QBR (70%)	Qx (10%)			1.5	0.5
11600	11690	90	CLU/Sands and Gravels	Sands and Gravels (20%)	QBR (70%)	Qx (10%)			1.5	0.5
11690	11760	70	CLU/Sands and Gravels	QBR (60%)	Fluvio-Glacial Sands (20%)	Qx (20%)			1.5	0.5
11760	12120	360	CLU/Sands and Gravels	Sands and Gravels (40%)	QBR (40%)	Qx (20%)			1.5	0.4
12120	12160	40	CLU/Sands and Gravels	Fluvio-Glacial Sands (50%)	QBR (40%)	Qx (10%)			1.5	0.3
12280	12300	20	Sands and Gravels	Sands and Gravels (20%)	QBR (40%)	Fluvio-Glacial Sands (20%)	Qx (20%)		1.5	0.4
12300	12400	100	Sands and Gravels/QBR	QBR (90%)	Qx (10%)				1.5	0.5
12400	12480	80	QBR	QBR (60%)	Fluvio-Glacial Sands (30%)	Qx (10%)			1.5	0.5
12480	12660	180	QBR/Fluvio-Glacial sands	Fluvio-Glacial Sands (40%)	QBR (50%)	Qx (10%)			1.5	0.5
12660	12720	60	QBR/Fluvio-Glacial sands/Sands and Gravels/CLU	Fluvio-Glacial Sands (60%)	QBR (30%)	Qx (10%)			1.5	0.3
12720	12900	180	Sands and Gravels/CLU	Fluvio-Glacial Sands (70%)	QBR (20%)	Qx (10%)			1.5	0.3
12900	13000	100	CLU	CLU (20%)	Sands and Gravels (30%)	QBR (20%)	Fluvio-Glacial Sands (20%)	Qx (10%)	1.5	0.4

Start Chainage	End Chainage	Length (m)	Excavated Material	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Vs (%)	K
13000	13220	220	**CLU**	**CLU (20%)**	**Sands and Gravels (20%)**	**QBR (30%)**	**Fluvio-Glacial Sands (20%)**	**Qx (10%)**	**0.75**	**0.4**
13220	13380	160	**CLU**	**CLU (20%)**	**Sands and Gravels (20%)**	**Fluvio-Glacial Sands (30%)**	**QBR (20%)**	**Qx (10%)**	**0.75**	**0.4**
13380	13420	40	**CLU**	**CLU (30%)**	**Sands and Gravels (20%)**	**QBR (40%)**	**Qx (10%)**		**0.75**	**0.4**
13420	13620	200	CLU	CLU (20%)	Sands and Gravels (10%)	QBR (60%)	Qx (10%)		1.5	0.5
13620	13700	80	**CLU**	**CLU (30%)**	**Sands and Gravels (20%)**	**QBR (40%)**	**Qx (10%)**		**0.75**	**0.4**
13700	13740	40	CLU	CLU (10%)	Sands and Gravels (40%)	QBR (40%)	Qx (10%)		1.5	0.4
13740	13760	20	CLU/Weathered rock/Sands and Gravels	Sands and Gravels (50%)	QBR (40%)	Qx (10%)			1.5	0.3
13880	14200	320	CLU	CLU (30%)	Sands and Gravels (30%)	QBR (20%)	Qx (20%)		1.5	0.4
14200	14320	120	**CLU**	**CLU (40%)**	**Sands and Gravels (20%)**	**QBR (20%)**	**Qx (20%)**		**0.75**	**0.4**
14320	14430	110	CLU	CLU (30%)	Sands and Gravels (30%)	QBR (20%)	Qx (20%)		1.5	0.4
14430	14530	100	CLU/Sands and Gravels/QBR	QBR (80%)	Qx (20%)				1.5	0.5
14530	14680	150	CLU/Sands and Gravels/QBR	Sands and Gravels (20%)	QBR (60%)	Fluvio-Glacial Sands (10%)	Qx (10%)		1.5	0.5
14680	14820	140	CLU/Sands and Gravels/QBR	Fluvio-Glacial Sands (40%)	QBR (40%)	Qx (20%)			1.5	0.4
14920	15000	80	CLU/Sands and Gravels/QBR	QBR (80%)	Qx (20%)				1.5	0.5
15000	15120	120	CLU/Sands and Gravels	QBR (80%)	Qx (20%)				1.5	0.5
15120	15440	320	CLU/Sands and Gravels	QBR (50%)	Fluvio-Glacial Sands (30%)	Qx (20%)			1.5	0.5
15440	15520	80	CLU/Sands and Gravels	QBR (40%)	Fluvio-Glacial Sands (40%)	Qx (20%)			1.5	0.4
15520	15600	80	CLU/Sands and Gravels/QBR	Fluvio-Glacial Sands (50%)	QBR (30%)	Qx (20%)			1.5	0.3
15700	16050	350	Sands and Gravels/QBR/Fluvio-Glacial Sands/CLU	Fluvio-Glacial Sands (60%)	QBR (30%)	Qx (10%)			1.5	0.3
16050	16260	210	Sands and Gravels/QBR/Fluvio-Glacial Sands/CLU	Fluvio-Glacial Sands (70%)	QBR (20%)	Qx (10%)			1.5	0.3
16260	16600	340	Sands and Gravels/Fluvio-Glacial Sands/CLU	Fluvio-Glacial Sands (80%)	QBR (10%)	Qx (10%)			1.5	0.3
16740	16840	100	CLU	Sands and Gravels (30%)	Fluvio-Glacial Sands (50%)	QBR (10%)	Qx (10%)		1.5	0.3
16840	16880	40	CLU	CLU (40%)	Sands and Gravels (20%)	QBR (20%)	QAG (10%)	Qx (10%)	1.5	0.4
16880	16960	80	**CLU**	**CLU (40%)**	**Sands and Gravels (20%)**	**QBR (20%)**	**QAG (10%)**	**Qx (10%)**	**0.75**	**0.4**
16960	17060	100	CLU	CLU (30%)	Sands and Gravels (20%)	QAG (30%)	Qx (20%)		1.5	0.3
17060	17100	40	CLU	Sands and Gravels (30%)	QAG (50%)	Qx (20%)			1.5	0.3
17100	17300	200	CLU	CLU (30%)	Sands and Gravels (20%)	QAG (30%)	Qx (20%)		1.5	0.3
17300	17360	60	**CLU**	**CLU (40%)**	**Sands and Gravels (20%)**	**QAG (20%)**	**Qx (20%)**		**0.75**	**0.4**
17460	17600	140	**CLU**	**CLU (40%)**	**Sands and Gravels (20%)**	**QAG (20%)**	**Qx (20%)**		**0.75**	**0.4**
17600	17690	90	CLU	CLU (20%)	Sands and Gravels (10%)	QBR (10%)	QAG (40%)	Qx (20%)	1.5	0.3
17690	17860	170	**CLU**	**CLU (50%)**	**Sands and Gravels (20%)**	**QBR (20%)**	**Qx (10%)**		**0.75**	**0.4**
17860	18180	320	**CLU**	**CLU (50%)**	**Sands and Gravels (20%)**	**Fluvio-Glacial Sands (20%)**	**Qx (10%)**		**0.75**	**0.4**
18180	18420	220	**CLU**	**CLU (40%)**	**Sands and Gravels (20%)**	**QBR (30%)**	**Qx (10%)**		**0.75**	**0.4**
18540	18900	360	**CLU**	**CLU (40%)**	**Sands and Gravels (30%)**	**QBR (20%)**	**Qx (10%)**		**0.75**	**0.4**

Start Chainage	End Chainage	Length (m)	Excavated Material	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Vs (%)	K
18900	18960	60	CLU	CLU (20%)	Sands and Gravels (20%)	QBR (30%)	Qx (30%)		1.5	0.3
18960	18980	20	**CLU**	**CLU (40%)**	**Sands and Gravels (30%)**	**QBR (10%)**	**Qx (20%)**		**0.75**	**0.4**
18980	19100	120	CLU	CLU (20%)	Sands and Gravels (20%)	QBR (30%)	Qx (30%)		1.5	0.4
19100	19160	60	**CLU**	**CLU (40%)**	**Sands and Gravels (20%)**	**QBR (20%)**	**Qx (20%)**		**0.75**	**0.4**
19160	19240	80	CLU	CLU (20%)	Sands and Gravels (20%)	QBR (30%)	Qx (30%)		1.5	0.4
19240	19300	60	**CLU**	**CLU (40%)**	**Sands and Gravels (20%)**	**QBR (20%)**	**Qx (20%)**		**0.75**	**0.4**
19420	19760	340	**CLU**	**CLU (40%)**	**Sands and Gravels (20%)**	**QBR (20%)**	**Qx (20%)**		**0.75**	**0.4**

5.2 Phase 2a Building Assessment Results

5.2.1 Representative Buildings

Initial Phase 2a Assessment

The initial Phase 2a assessment results for the 'representative' buildings are given in Table 5-2 together with the key relevant building information. The actual location of the building and the worst-case orientation line that passes through the footprint of the buildings (i.e., close to being orthogonal to the settlement contour) have been determined from the OS Map.

The initial Phase 2a assessment shows that the following nine buildings fall within Damage Category 3:

B39, B76, B77, B142, B175, B176, B177, B178 & B179.

Refined Phase 2a Assessment

Considering the nine buildings which fell within Damage Category 3 at the end of the initial Phase 2a assessment, a refined Phase 2a assessment has been carried out with tighter volume loss values considering the advances in tunnelling equipment and control due to the capability of the TBM that will be used, and the Damage Category of all the buildings reassessed. In the refined Phase 2a assessment, the volume loss values have been taken as two-thirds of the corresponding values adopted for the initial Phase 2a as follows:

- Superficial material (clay or granular material): V_l = 1.0%
- Rock strata: V_l = 0.5%

In the case of a mixed strata:

- If the tunnel is wholly in rock and there is at least half-a-tunnel diameter rock cover above the crown, then V_l = 0.5%;
- Else V_l = 1.0%.

These volume loss values are compatible with those experienced using modern tunnelling equipment and control systems from variable density TBMs which it is anticipated will be employed for this project.

For the non-TBM construction, current methodologies with instrumentation and monitoring from the surface providing information to inform the control at the face also improve the losses that can be anticipated and allows the volume loss values to be taken as 50% more than that of the corresponding TBM volume loss values.

These values are moderatly conservate when comparing against the published data in CIRIA PR 30 for stiff fissured clay and glacial deposits.

The refined Phase 2a assessment results show that all the 'representative' buildings fall within Damage Category 2 or below.

5.2.2 Generic Terrace House Building

In addition to the 'representative' buildings, there are other buildings which qualified for Phase 2a assessment as a result of falling within the 10mm contour. It is noted, particularly in the northern central section of the alignment between Ballymun and Glasnevin stations, many of the residential properties are two storey terraced houses. Therefore, in order to streamline the building assessment process further, generic buildings of different lengths have been assessed, positioned at 10m intervals along the tunnel route, and a Phase 2a assessment carried out adopting the refined tunnelling volume loss parameters. The generic building is orientated orthogonal to the tunnel

alignment, thus subject to the most onerous effects of ground movement; with this approach, it is possible to eliminate a large number of buildings from building-specific assessment process where the generic building assessment indicates that they fall below Damage Category 3 in any region.

The generic building adopted for this process has the following characteristics (typical terraced house):

- 6m high
- 20m, 30m, 40m, 50m, 60m, 80m lengths centred symmetrically across the tunnel centreline
- Masonry construction
- No basements

The results of the generic building assessment are given in Table 5-3. It is evident from the table that except at station/portal locations, there are only two limited zones (Ch 13+980 to Ch 14+040, and Ch 17+160 to Ch 17+220) that a typical terraced house will be subject to potential Damage Category 3 or above; these zones are associated with tunnelling zones with no or limited rock cover. The generic assessment results have been used to identify any terraced houses in these zones and in the vicinity of the stations/portals that fall within the 10mm contour. These buildings have then been the subject of a building specific damage assessment, taking account of the actual length, position and orientation of the building which meant the generic assessed damage category will improve.

Although the generic assessment exercise eliminated the need for building specific analyses over a considerable length of the alignment, any buildings taller than a two-storey terraced or other building type still requires a building specific assessment as explained by the following section.

5.2.3 Additional Buildings

In addition to the ‘representative’ buildings, building specific assessments have been carried out for the following:

- two-storey terraced houses that have been identified as being at risk of damage greater than Category 2 based on the above-described generic assessment; and
- those buildings greater than a two-storey terraced houses which are not already included in the list of ‘representative’ buildings.

These buildings are termed as ‘additional’ buildings (‘additional’ to the ‘representative’ buildings identified in Section 4.6) in this report and are listed in Table 5-4 together with their corresponding building specific impact assessment result. The impact assessment has taken account of specific building height and assumes the buildings are supported on shallow foundations with no basement.

The refined Phase 2a assessment results for the ‘additional’ buildings show that all the buildings, except AB11 and AB13 (terraced residential blocks south of Griffith Park station), fall within Damage Category 2 or below. A treatment strategy for buildings AB11 and AB13 is proposed under section 5.4.

5.3 Impact Due to Corner Stiffening at Station Box Excavations

Additional analyses have been carried out on five selected buildings which are located at the corners of the proposed station boxes and therefore could potentially be impacted by corner stiffening effects as described by section 1.3.2.

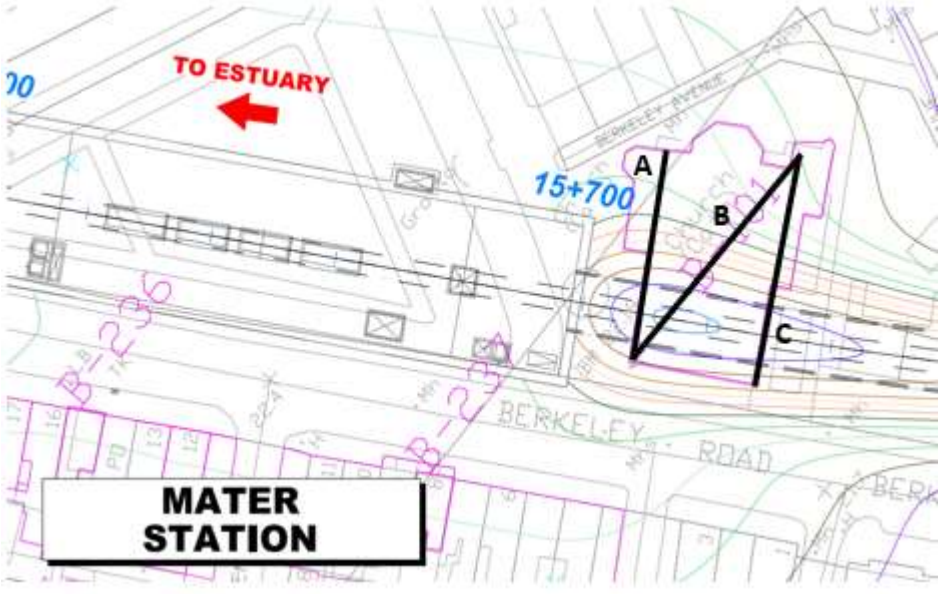
The calculated maximum tension values with and without corner stiffening effects are compared in Table 5-5. The corresponding displacement lines are shown by Figure 5-1. Although in some cases the maximum tensile strain

values have increased when corner stiffening effects are considered, the assessed building damage does not exceed Category 2.

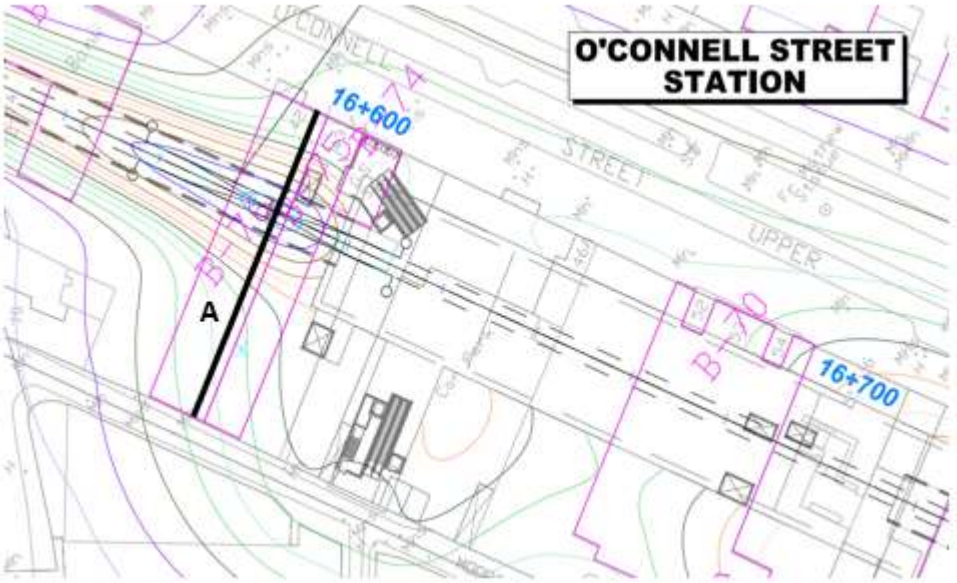
Despite the damage classification from both the initial and the refined analysis of the Carrolls Building at chainage 19300 table 5-5 intervention may be required. This is due to the proximity of the building, figure 5.1 e to the Charlemont station structure. Local effects including variation in ground, the building ground and construction technique can influence the predictions. Therefore, it is prudent to anticipate a potential intervention around the structure until these are all known. This could be mitigated with very precise construction control, the installation of a physical separation, or ground treatment to prevent any movement.

Table 5-5: Results of Maximum Tensile Strain With and Without Corner Stiffening Effect (Refined Phase 2a Assessment)

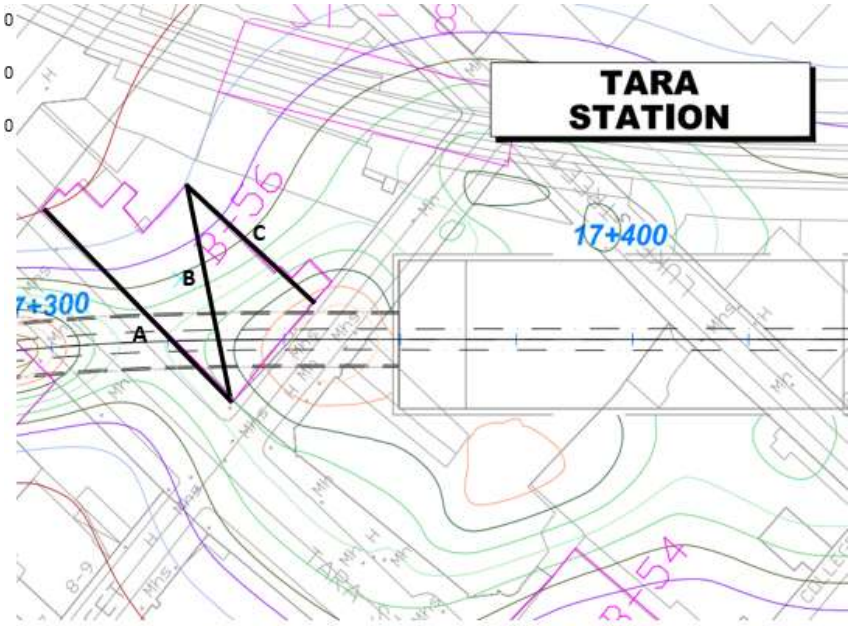
Building No & Line	With Corner Stiffening (Option 2)		Without Corner Stiffening (Option 1)	
	Maximum tensile strain	Damage Category	Maximum tensile strain	Damage Category
101a	0.072	1 (Very slight)	0.059	1 (Very slight)
101b	0.087	2 (Slight)	0.060	1 (Very slight)
101c	0.082	2 (Slight)	0.067	1 (Very slight)
76	0.086	2 (Slight)	0.074	1 (Very slight)
56a	0.053	1 (Very slight)	0.078	2 (Slight)
56b	0.067	1 (Very slight)	0.050	1 (Very slight)
56c	0.128	2 (Slight)	0.106	2 (Slight)
51a	0.023	0 (Negligible)	0.021	0 (Negligible)
51b	0.048	0 (Negligible)	0.048	0 (Negligible)
51c	0.102	2 (Slight)	0.112	2 (Slight)
228a	0.140	2 (Slight)	0.098	2 (Slight)
228b	0.077	2 (slight)	0.140	2 (Slight)



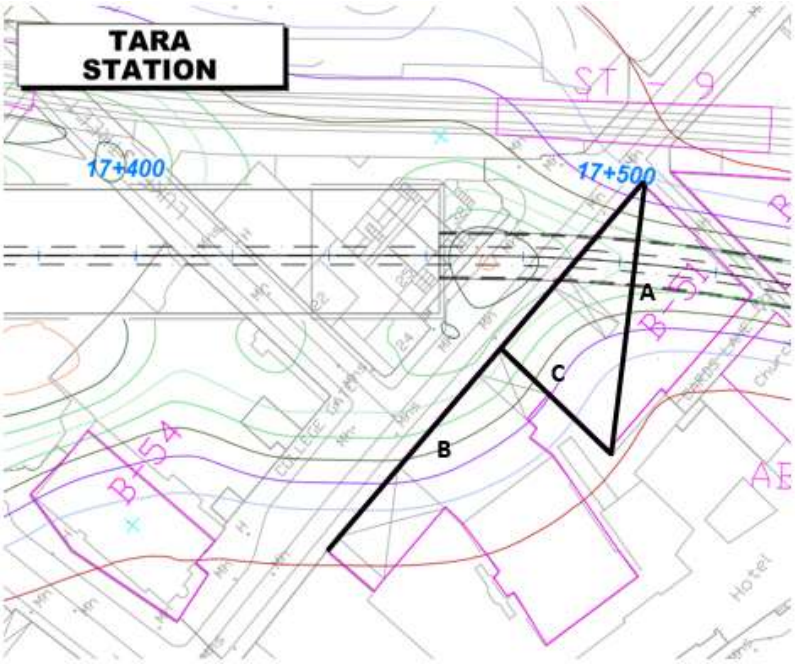
a) Building B-101



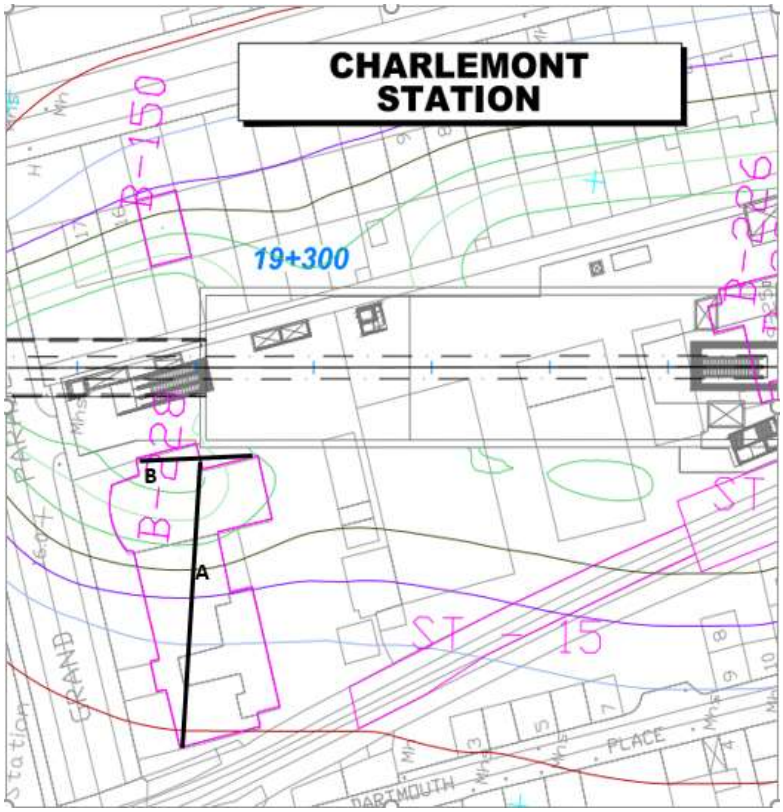
b) Building B-76



c) Building B-56



d) Building B-51



e) Building B-228

Figure 5.1: Displacement Lines Considered for Buildings At The Corners Of Proposed Station Boxes

5.4 Assessment Summary and Conclusions

On conclusion of the refined Phase 2a assessment, all the 'representative' buildings have been assessed as falling into Damage Category 2 or below. Damage Category 2 means that the degree of damage will be 'slight' (refer to Table 4-4), and any repair works would constitute activities similar to standard maintenance work. Further, except for AB11 & AB13 (terraced residential blocks south of Griffith Park station), all the 'additional' buildings also fall into Damage Category 2 or below. For the two terraced residential blocks, AB11 & AB13, it is likely that the detailed Phase 3 assessment will bring the damage category level to below Damage Category 2. If not, it is considered that post MetroLink construction, repair, together with an appropriate instrumentation and monitoring strategy, would be a more economical and practicable treatment strategy for these buildings rather than more disruptive and intrusive pre-construction protection measures.

As part of the Phase 2b assessment, the D&B Contractor will review and refine the Phase 2a assessment results based on updated survey information, detail design development (increased design maturity) and finalising his construction methodology and planning.

Irrespective of the Phase 2b assessment results, all the 'special' buildings (refer to section 4.1) amongst the 'representative' buildings shall be subject to a Phase 3 assessment by the D&B Contractor. Table 5-2 identifies the 'special' buildings and the basis on which they have been passed to the next stage of assessment i.e. whether they are designated Protected Structures, or deemed to be sensitive buildings, or are in close proximity to excavation boundaries, or because they have a basement greater than 4m deep.

No further assessment will be required for the 'special' buildings which fall outside the 1mm contour.

In particular, some form of foundation treatment might be required to protect the Carrolls Building (B-228) due to its very close proximity (less than 2m) to the proposed excavation associated with Charlemont station box construction.

Table 5-2: Result of Phase 2a Building Damage Assessment – Representative Buildings

Ref	Chainage	Description	Height (m)	Number of Floors	Length (m)	Depth of basement (m)	Initial Phase 2a Assessment Damage Category	Refined Phase 2a Assessment Damage Category	RPS, NIAH, RMP or other heritage (Y/N/unknown)	Continue to next assessment phase? (Y/N)	Comments
B-1	18620	Permanent TSB Head Office	20.0	4	64.9	-2.5	N/A	N/A	Y	N	Outside 1mm contour
B-2	18580	Loreto College	20.0	4	88.9	-3.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-3	18500	OPW	25.0	6	111.3	-3.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-4	18520	Department of Justice and Equality	20.0	3	60.7	-2.5	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-5	18480	Australian Embassy	20.0	5	39.8	-2.5	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-6	18460	Housing Finance Agency	20.0	5	32.9	0.0	2 (Slight)	2 (Slight)	N	N	Damage category 2 or below
B-7	18420	Ivor Fitzpatrick and Co	20.0	5	31.6	-2.5	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-8	18400	Boston College - St. Stephen's Green	13.0	4	22.2	-2.5	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-9	18380	Forty-One Restaurant	16.0	3	29.0	-2.5	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-10	18380	Bank of Ireland	15.0	3	26.1	-3.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-11	18340	International Rugby Board	24.0	7	26.0	-3.1	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-12	18340	The Spa	30.0	7	18.5	-6.6	1 (Very Slight)	0 (Negligible)	Y	Y	Special building Case B too (refer to section 4.1)
B-13	18320	Shelbourne Hotel	30.0	7	40.4	-6.6	0 (Negligible)	0 (Negligible)	Y	Y	Special building Case B too (refer to section 4.1)
B-14	18280	Department of Agriculture, Food & Marine	31.0	8	40.5	-4.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-15	18240	Government Building	14.0	4	28.7	-3.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-16	18080	Government Building	21.0	6	24.9	-3.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-17	18120	Irish Parliament	14.0	4	19.2	-6.2	0 (Negligible)	0 (Negligible)	Y	Y	Special building Case B too (refer to section 4.1)
B-18	18180	National Museum of Ireland	20.0	2	69.2	-3.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-19	18160	Natural History Museum	16.0	2	68.7	-3.0	N/A	N/A	Y	N	Outside 1mm contour
B-20	18080	National Library	14.0	4	66.9	-5.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building Case B too (refer to section 4.1)
B-21	17980	National Gallery of Ireland	25.0	5	37.4	-5.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building Case B too (refer to section 4.1)
B-22	17980	Trinity Point	17.5	5	9.4	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-23	18020	Trinity Point	21.0	6	28.8	0.0	N/A	N/A	N	N	Outside 1mm contour
B-24	18020	Trinity Point	17.5	5	9.4	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-25	17980	Student Counselling Service	14.0	4	8.5	0.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-26	18020	National Gallery of Ireland	25.0	5	71.8	-5.0	N/A	N/A	Y	N	Outside 1mm contour
B-27	18020	National Gallery of Ireland	25.0	5	35.3	-6.8	0 (Negligible)	0 (Negligible)	Y	Y	Special building Case B too (refer to section 4.1)
B-28	17980	Residential	15.0	4	30.7	-2.5	N/A	N/A	N	N	Outside 1mm contour
B-29	17940	Residential	14.0	4	11.6	-2.3	N/A	N/A	Y	N	Outside 1mm contour
B-30	17940	Insomnia	19.0	4	2.7	-2.4	0 (Negligible)	0 (Negligible)	Y	Y	Special building

Ref	Chainage	Description	Height (m)	Number of Floors	Length (m)	Depth of basement (m)	Initial Phase 2a Assessment Damage Category	Refined Phase 2a Assessment Damage Category	RPS, NIAH, RMP or other heritage (Y/N/unknown)	Continue to next assessment phase? (Y/N)	Comments
B-31	17920	Trinity College	19.0	4	19.9	-2.5	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-32	17900	Dept. of Mechanical Manufacturing Engineering	10.5	3	18.9	0.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-33	17900	Dublin Dental University Hospital	19.0	4	3.3	-2.5	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-34	17880	Dublin Dental University Hospital	19.0	4	3.3	-2.5	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-35	17840	Trinity College-Zoology	10.5	3	15.6	0.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-36	17800	Trinity College-Chemistry	10.5	3	56.1	0.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-37	17740	Trinity College-Laser Unit	17.5	5	30.6	0.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-38	17760	Trinity College-Physics	14.0	4	18.0	0.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-39	17720	Trinity College-Botanics	7.0	2	18.2	0.0	3 (Moderate)	2 (Slight)	Y	Y	Special building
B-40	17700	Luce Hall	17.5	5	1.3	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-41	17680	Engineering Laboratory	14.0	4	61.1	0.0	2 (Slight)	2 (Slight)	Y	Y	Special building
B-42	17660	Trinity Business School	10.5	3	5.5	0.0	2 (Slight)	2 (Slight)	Y	Y	Special building
B-43	17640	St Marks Church if Ireland	17.6	2	40.2	-1.8	N/A	N/A	Y	N	Outside 1mm contour
B-44	17620	GoHop - Ireland's Internet Travel Company	13.0	3	14.7	-2.8	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-45	17620	O'Neills Whiskey Bonders	12.0	3	4.1	-2.0	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-46	17600	O'Neills Town House	14.0	3	12.0	-2.0	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-47	17600	World Travel	11.6	3	6.3	-2.2	1 (Very Slight)	0 (Negligible)	Y	Y	Special building
B-48	17580	The School Tour company	11.6	3	0.4	-2.2	1 (Very Slight)	0 (Negligible)	Y	Y	Special building
B-49	17560	Mc Carty Centre	18.5	5	30.2	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-50	17540	Solvar Fields Ltd.	26.0	4	6.3	-3.5	1 (Very Slight)	0 (Negligible)	N	N	Demolished
B-51	17500	Dublin Fire Brigade & Commercial	30.0	6	13.1	-2.5	0 (Negligible)	0 (Negligible)	Y	Y	Special building Case A too (refer to section 4.1)
B-52	18840	National Concert Hall	10.5	3	117.3	0.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-53	18920	Public	14.0	4	3.0	0.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-54	17400	The Irish Times	36.0	7	37.9	-3.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building Case A too (refer to section 4.1)
B-55	18980	Residential	19.0	4	14.5	-2.0	1 (Very Slight)	0 (Negligible)	Y	Y	Special building
B-56	17320	Tara House	10.5	3	11.9	0.0	1 (Very Slight)	1 (Very Slight)	N	N	Demolished
B-57	17260	Starbucks Coffee	16.0	5	6.6	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-58	17220	Corn Exchange Apartments	14.0	2	25.2	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-59	17120	Eden House	14.0	4	32.5	-3.7	2 (Slight)	2 (Slight)	Y	Y	Special building
B-60	17100	Abbey Theatre	14.0	4	50.9	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-62	17040	Methodist Church	14.0	4	30.8	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-64	16980	College	17.5	5	42.4	0.0	N/A	N/A	N	N	Outside 1mm contour

Ref	Chainage	Description	Height (m)	Number of Floors	Length (m)	Depth of basement (m)	Initial Phase 2a Assessment Damage Category	Refined Phase 2a Assessment Damage Category	RPS, NIAH, RMP or other heritage (Y/N/unknown)	Continue to next assessment phase? (Y/N)	Comments
B-65	16920	Clearys Shopcenter	14.0	4	91.1	0.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-66	16860	Ann Summers	17.5	5	29.0	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-67	16860	General Post Office	20.0	5	5.3	-2.8	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-68	16800	McDowels	21.0	6	13.3	-3.0	N/A	N/A	Y	N	Outside 1mm contour
B-69	16720	St Mary's Catholic Pro Cathedral	14.0	4	47.5	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-70	16680	Carlton Theatre	20.0	3	15.4	0.0	To be demolished	To be demolished	Y	N	To be demolished
B-71	16660	Savoy Cinema	17.5	5	55.3	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-72	16600	The Gresham Hotel - O'Connell Street Station	17.5	5	55.9	-3.0	N/A	N/A	Y	N	Outside 1mm contour
B-74	16600	44 O'Connell Street	14.0	4	15.3	0.0	To be demolished	To be demolished	Y	N	To be demolished
B-75	16600	43 O'Connell Street	17.2	5	16.8	-3.3	To be demolished	To be demolished	Y	N	To be demolished
B-76	16580	42 O'Connell Street	20.0	4	16.8	-3.9	3 (Moderate)	2 (Slight)	Y	Y	Special building Case A too (refer to section 4.1)
B-77	16540	AIB Bank	18.0	4	17.1	-3.4	3 (Moderate)	2 (Slight)	Y	Y	Special building
B-78	16500	Parnell Monument	19.0	4	14.2	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-79	16480	Rotunda Hospital, Parnell Square East	14.0	4	133.2	-3.0	2 (Slight)	2 (Slight)	Y	Y	Special building
B-80	16400	Rotunda IVF clinic	7.0	2	30.7	0.0	2 (Slight)	2 (Slight)	Y	Y	Special building
B-81	16460	The Ambassador Theatre	14.0	4	18.1	-3.0	2 (Slight)	2 (Slight)	Y	Y	Special building
B-82	16440	Gate Theatre	10.5	3	15.5	-3.0	2 (Slight)	2 (Slight)	Y	Y	Special building
B-83	16460	Netprint Café	12.0	4	22.2	-1.6	N/A	N/A	Y	N	Outside 1mm contour
B-84	16440	Cassidys Hotel	14.0	4	47.5	-1.7	N/A	N/A	Y	N	Outside 1mm contour
B-85	16440	Cassidys Hotel	14.0	4	47.5	-1.7	N/A	N/A	Y	N	Outside 1mm contour
B-86	16420	Residential	14.0	4	32.9	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-87	16380	Gaelscoil Cholaiste Mhuire & The Charles Stewart Dublin - Guest Accommodation	16.0	4	60.7	-3.3	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-88	16320	Youthreach Transition Centre	14.0	4	28.7	0.0	1 (Very Slight)	0 (Negligible)	Y	Y	Special building
B-89	16280	Residential	14.0	4	62.6	0.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-90	16240	Abbey Presbyterian Church	8.0	2	19.4	-2.6	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-91	16200	Residential Houses & Hotels	14.5	5	22.8	-3.4	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-92	16140	Residential	12.5	4	29.3	-3.0	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-93	16100	Capital Loan	12.0	4	22.7	-2.6	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-94	16080	Finn Travel Agency	12.5	4	16.2	-3.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-95	16020	Sackvile Court Apartments	15.0	5	18.4	0.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-96	15980	Embassy	14.0	4	21.1	-1.6	2 (Slight)	1 (Very Slight)	Y	Y	Special building

Ref	Chainage	Description	Height (m)	Number of Floors	Length (m)	Depth of basement (m)	Initial Phase 2a Assessment Damage Category	Refined Phase 2a Assessment Damage Category	RPS, NIAH, RMP or other heritage (Y/N/unknown)	Continue to next assessment phase? (Y/N)	Comments
B-97	15940	Residential	14.0	4	9.6	0.0	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-98	15920	Residential	9.0	4	17.0	-1.5	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-99	15860	Residential	10.0	3	19.8	-2.5	2 (Slight)	2 (Slight)	Y	Y	Special building
B-100	15820	Residential	10.5	3	5.3	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-101	15720	St. Joseph's Church	20.0	5	31.1	-2.2	2 (Slight)	1 (Very Slight)	Y	Y	Special building Case A too (refer to section 4.1)
B-102	15560	Mater Misericordia Hospital	10.5	3	227.0	-3.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building Case A too (refer to section 4.1)
B-103	15540	Deli Fruit Selections	7.0	2	12.7	0.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-104	15540	Residential	7.0	2	12.7	0.0	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-105	15460	Group of Residential Houses	6.5	2	12.6	-1.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-106	15440	Residential	8.5	2	7.1	-1.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-107	15420	Residential	11.5	3	15.4	-0.8	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-108	15400	Jyoti Yoga Shala	11.0	3	8.2	-2.5	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-109	15360	The Butchers	7.0	2	19.2	-0.8	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-110	15340	Library View Villas	7.2	2	7.9	-1.2	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-111	15340	Phibsboro Library	6.0	1	24.9	-1.2	1 (Very Slight)	0 (Negligible)	Y	Y	Special building
B-112	15320	Residential complex	14.0	4	40.2	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-113	15220	McDonalds	10.0	2	32.8	0.0	1 (Very Slight)	0 (Negligible)	N	N	Damage category 2 or below
B-114	15200	Commercial	3.0	1	16.2	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-115	15160	Residential	10.5	3	9.8	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-116	15080	Residential	7.0	2	20.1	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-117	14980	Commercial	10.5	3	14.4	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-118	14980	Residential	14.0	4	9.8	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-119	14700	Hotel	7.0	2	8.4	0.0	1 (Very Slight)	0 (Negligible)	N	N	Damage category 2 or below
B-120	14580	Residential	7.0	2	13.9	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-121	14760	Residential Houses	5.4	2	6.9	-1.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-122	14520	Hotel	9.0	3	6.4	-1.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-123	14400	Residential Houses	7.0	2	21.0	0.0	2 (Slight)	2 (Slight)	N	N	Damage category 2 or below
B-124	12200	Victories Church; Collins Avenue Station	7.0	2	59.8	0.0	2 (Slight)	2 (Slight)	N	N	Damage category 2 or below
B-125	11920	Ballymun Library	4.7	1	25.7	0.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-126	11780	CEBT-Adult Education Service	4.7	1	28.3	0.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-127	11400	Ballymun Leisure Centre	17.5	5	78.3	-3.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-128	11460	Gateway Students Village	14.0	4	35.4	0.0	N/A	N/A	N	N	Outside 1mm contour

Ref	Chainage	Description	Height (m)	Number of Floors	Length (m)	Depth of basement (m)	Initial Phase 2a Assessment Damage Category	Refined Phase 2a Assessment Damage Category	RPS, NIAH, RMP or other heritage (Y/N/unknown)	Continue to next assessment phase? (Y/N)	Comments
B-129	11360	Ballymun Civic Centre	14.0	4	74.6	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-130	10860	Maleston Apartments	21.0	6	36.2	0.0	N/A	N/A	N	N	Outside 1mm contour
B-131	7300	Terminal 2, Terminal Complex, Dublin Airport, Swords, Co. Dublin	17.5	5	24.5	-3.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-132	6820	Airport Hangers	7.0	2	291.4	0.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-133	5120	Fuel Station	3.5	1	33.9	0.0	1 (Very Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-134	4840	Smyths Toys Superstores. Commercial Centre	14.0	4	46.1	0.0	To be demolished	To be demolished	N	N	End unit to be demolished
B-135	4840	Residential Houses	7.0	2	11.0	0.0	N/A	N/A	N	N	Outside 1mm contour
B-136	4000	Fujitsu Ireland Ltd.	10.5	3	79.5	-1.5	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-139	14560	Residential	7.0	2	8.1	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-140	14560	Residential	7.0	2	8.7	-1.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-141	14480	Residential	7.0	2	11.1	0.0	1 (Very Slight)	0 (Negligible)	N	N	Damage category 2 or below
B-142	13940	Residential	5.5	2	11.2	0.0	3 (Moderate)	2 (Slight)	N	N	Damage category 2 or below
B-143	13840	Whitehall College	12.5	3	84.7	-3.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-144	13460	Residential	7.0	2	10.4	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-145	12900	Residential	8.8	2	12.9	0.0	1 (Very Slight)	0 (Negligible)	Y	Y	Special building
B-146	16700	Unknown	17.5	5	17.9	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-147	19020	Davitt House	12.0	4	26.0	-2.5	2 (Slight)	2 (Slight)	N	N	Damage category 2 or below
B-148	19100	Residential	11.8	3	37.8	0.0	0 (Negligible)	0 (Negligible)	Y	Y	Special building
B-149	19160	Residential	15.0	4	17.4	-2.5	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-150	19300	Residential	10.5	3	12.1	0.0	2 (Slight)	2 (Slight)	Y	Y	Special building Case A too (refer to section 4.1)
B-151	19440	Residential	7.0	2	10.6	0.0	2 (Slight)	2 (Slight)	Y	Y	Special building Case A too (refer to section 4.1)
B-152	19480	Residential	7.0	2	10.0	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-153	19600	Unknown	7.0	2	6.6	0.0	N/A	N/A	N	N	Outside 1mm contour
B-155	20055	Residential	10.5	3	17.1	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-156	20148	Unknown	7.0	2	5.5	0.0	N/A	N/A	N	N	Outside 1mm contour
B-157	14800	Residential	10.5	3	20.4	0.0	1 (Very Slight)	0 (Negligible)	N	Y	Damage category 2 or below Case A (refer to section 4.1)
B-158	14220	Bank of Ireland	7.0	2	19.7	0.0	1 (Very Slight)	0 (Negligible)	N	N	Damage category 2 or below
B-159	14000	Residential	7.0	2	10.0	0.0	2 (Slight)	2 (Slight)	N	N	Damage category 2 or below
B-160	14000	Residential	6.0	2	3.3	0.0	2 (Slight)	2 (Slight)	N	N	Damage category 2 or below
B-161	13160	Residential	8.8	2	9.6	-1.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-162	13180	Residential	7.0	2	12.2	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-163	13140	Residential	7.0	2	8.9	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below

Ref	Chainage	Description	Height (m)	Number of Floors	Length (m)	Depth of basement (m)	Initial Phase 2a Assessment Damage Category	Refined Phase 2a Assessment Damage Category	RPS, NIAH, RMP or other heritage (Y/N/unknown)	Continue to next assessment phase? (Y/N)	Comments
B-164	13120	Residential	8.7	2	11.7	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-165	10760	Residential	12.5	4	56.4	-3.6	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-166	7580	Terminal 2 Gates 407 to 426, Terminal Complex, Dublin Airport, Swords, Co. Dublin	14.0	4	78.5	-3.0	1 (Very Slight)	0 (Negligible)	N	N	Damage category 2 or below
B-167	6980	Dublin Airport Parking	17.5	5	96.0	-3.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-168	5120	Nevinstown Lodge, Nevinstown West, Swords, Co. Dublin	3.5	1	5.0	0.0	to be demolished	to be demolished	N	N	Overlaps retained cut, assumed to be demolished
B-172	17080	Emerald Casino	14.0	4	25.8	-2.4	2 (Slight)	2 (Slight)	Y	Y	Special building
B-173	17080	Clifton Court Bar	17.5	5	29.5	0.0	2 (Slight)	2 (Slight)	Y	Y	Special building
B-174	17080	Lanigans Restaurant	10.5	3	19.7	0.0	2 (Slight)	2 (Slight)	Y	N	Damage category 2 or below
B-175	17100	Samaritans Dublin	14.0	4	4.1	-2.6	3 (Moderate)	2 (Slight)	Y	Y	Special building
B-176	17080	Photocare	14.0	4	29.9	-2.5	3 (Moderate)	2 (Slight)	Y	Y	Special building
B-177	17060	Eurogiant	14.0	4	26.5	-3.8	3 (Moderate)	2 (Slight)	Y	Y	Special building
B-178	17060	Amplifon	14.0	4	12.8	-4.1	3 (Moderate)	2 (Slight)	Y	Y	Special building Case B too (refer to section 4.1)
B-179	17040	Spar	14.0	3	12.7	-3.7	3 (Moderate)	2 (Slight)	Y	Y	Special building
B-187	17000	Veritas.ie	14.0	4	27.8	0.0	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-188	17000	Reynolds	14.8	4	19.7	-3.4	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-189	17000	Ladbrokes	14.0	4	22.0	0.0	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-190	16980	Coojum Restaurant	17.5	5	9.7	0.0	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-191	16980	Permanent TSB	21.0	6	1.0	0.0	2 (Slight)	1 (Very Slight)	Y	Y	Special building
B-192	16960	Paddywagon	18.0	5	2.8	-3.0	2 (Slight)	2 (Slight)	Y	Y	Special building
B-193	16960	Londis	18.0	5	7.6	-2.7	2 (Slight)	2 (Slight)	N	N	Damage category 2 or below
B-194	16960	Indulge	21.0	6	4.3	0.0	2 (Slight)	2 (Slight)	N	N	Damage category 2 or below
B-195	16960	Office	21.0	6	26.6	0.0	2 (Slight)	2 (Slight)	Y	Y	Special building
B-198	16780	Unknown	15.0	4	12.5	-3.8	2 (Slight)	2 (Slight)	Y	Y	Special building
B-199	16780	Unknown	15.0	5	11.9	-3.9	2 (Slight)	2 (Slight)	Y	Y	Special building Case A too (refer to section 4.1)
B-200	16760	CoCoBo Chocolate	17.5	5	11.5	-3.6	2 (Slight)	2 (Slight)	Y	Y	Special building Case A too (refer to section 4.1)
B-201	15280	Residential apartments	14.0	4	27.1	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-202	14960	Residential apartments	24.5	7	43.7	0.0	1 (Very Slight)	0 (Negligible)	Y	Y	Special building
B-203	20048	Residential	7.0	2	11.2	0.0	N/A	N/A	N	N	Outside 1mm contour
B-204	20053	Residential	7.0	2	11.2	0.0	N/A	N/A	N	N	Outside 1mm contour
B-205	20058	Residential	8.5	2	11.0	0.0	N/A	N/A	N	N	Outside 1mm contour
B-206	20016	Residential	9.5	3	17.0	0.0	N/A	N/A	N	N	Outside 1mm contour

Ref	Chainage	Description	Height (m)	Number of Floors	Length (m)	Depth of basement (m)	Initial Phase 2a Assessment Damage Category	Refined Phase 2a Assessment Damage Category	RPS, NIAH, RMP or other heritage (Y/N/unknown)	Continue to next assessment phase? (Y/N)	Comments
B-207	19997	Residential	7.0	2	10.5	0.0	N/A	N/A	N	N	Outside 1mm contour
B-208	19999	Residential	7.0	2	10.4	0.0	N/A	N/A	N	N	Outside 1mm contour
B-209	19949	Commerce & Residential	11.0	3	14.5	0.0	N/A	N/A	N	N	Outside 1mm contour
B-210	19908	Commerce & Residential	8.3	2	11.9	0.0	N/A	N/A	N	N	Outside 1mm contour
B-211	19915	Commerce & Residential	8.3	2	7.8	0.0	N/A	N/A	N	N	Outside 1mm contour
B-212	19831	Residential	11.1	3	3.4	-2.3	N/A	N/A	Y	N	Outside 1mm contour
B-213	19820	Residential	11.1	3	4.5	-2.3	N/A	N/A	Y	N	Outside 1mm contour
B-214	19820	Commerce & Residential	9.4	2	18.0	0.0	N/A	N/A	N	N	Outside 1mm contour
B-215	19820	Commerce & Residential	9.4	2	17.6	0.0	N/A	N/A	N	N	Outside 1mm contour
B-217	19700	Kids Inc - Creche & Montessori, Ranelagh	10.0	3	21.5	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-218	19660	Residential	8.2	2	12.2	0.0	N/A	N/A	N	N	Outside 1mm contour
B-219	19660	Residential	8.1	2	12.3	0.0	N/A	N/A	N	N	Outside 1mm contour
B-220	19620	Residential	11.4	3	10.2	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-221	19620	Residential	11.4	3	11.0	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-222	19540	Residential	11.4	3	7.1	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-223	19540	Residential	11.4	3	7.6	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-224	19520	Residential	7.0	2	6.9	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-225	19520	Residential	7.0	2	6.7	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-228	19300	Carrolls Building	24.5	7	48.3	0.0	2 (Slight)	2 (Slight)	Y	Y	Special building Case A too (refer to section 4.1)
B-230	2840	Hertz, Swords Business Park, Swords, Co. Dublin	12.0	2	196.4	0.0	2 (Slight)	2 (Slight)	N	Y	Damage category 2 or below Case A (refer to section 4.1)
B-231	7040	Our Lady Queen of Corballis Heaven, Corballis Road North, Dublin Airport, Swords Co. Dublin	7.0	2	47.2	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-232	11480	The Sentinel Building, Gateway View, Dublin 11 - Apartments 1-8 & Retail Unit	31.5	9	11.2	0.0	1 (Very Slight)	0 (Negligible)	N	N	Damage category 2 or below
B-233	11500	Apartments 40-42, Gateway View Dublin 11	12.2	4	11.1	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-234	14820	Unknown	7.1	2	7.9	0.0	N/A	N/A	N	N	Outside 1mm contour
B-235	15460	54 Goldsmith St, Phibsborough, Dublin 7	3.5	1	14.7	0.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below
B-236	15620	15 Berkeley Road, Phibsborough, Dublin 7	7.0	2	17.2	0.0	1 (Very Slight)	1 (Very Slight)	N	Y	Damage category 2 or below Case A (refer to section 4.1)
B-237	15680	Residential	7.0	2	13.0	0.0	1 (Very Slight)	1 (Very Slight)	N	Y	Damage category 2 or below Case A (refer to section 4.1)
B-238	18980	Arthur Cox Building	40.0	7	17.8	-8.1	2 (Slight)	2 (Slight)	N	Y	Case B (refer to section 4.1)
B-239	13120	Residential	8.7	2	5.0	0.0	0 (Negligible)	0 (Negligible)	N	N	Damage category 2 or below
B-240	7060	Presbytery, Corballis Road North, Dublin Airport, Swords Co. Dublin	7.0	2	18.2	0.0	1 (Very Slight)	1 (Very Slight)	Y	Y	Special building

Ref	Chainage	Description	Height (m)	Number of Floors	Length (m)	Depth of basement (m)	Initial Phase 2a Assessment Damage Category	Refined Phase 2a Assessment Damage Category	RPS, NIAH, RMP or other heritage (Y/N/unknown)	Continue to next assessment phase? (Y/N)	Comments
B-241	17020	Hotel Winns	21.0	6	4.3	-3.0	2 (Slight)	2 (Slight)	Y	Y	Special building
B-242	19760	Residential	10.5	3	10.1	0.0	N/A	N/A	N	N	Outside 1mm contour
B-243	14840	Unknown	7.9	3	12.4	0.0	N/A	N/A	Y	N	Outside 1mm contour
B-244	14100	Lloyd Institute Trinity	7.0	2	11.0	0.0	2 (Slight)	1 (Very Slight)	N	N	Damage category 2 or below

Table 5-3: Results of Refined Phase 2a Building Damage Assessment – Generic Buildings

Zones of Potential Damage Category 3 for Terraced House Blocks of Different Length						
Height = 6m Length = 20m	**Height = 6m Length = 30m**	**Height = 6m Length = 40m**	**Height = 6m Length = 50m**	**Height = 6m Length = 60m**	**Height = 6m Length = 80m**	**Comments**
Ch 6000 – Ch 6060	Ch 6000 – Ch 6090	Ch 6000 – Ch 6090	Ch 6000 – Ch 6090	Ch 6000 – Ch 6090	Ch 6000 – Ch 6090	North Portal
	Ch 7130	Ch 7040 – Ch 7130	Ch 7000 – Ch 7130	Ch 7000 – Ch 7130	CH 7000 – Ch 7130	Dublin Airport Station
Ch 8350 – Ch 8470	Ch 8350 – Ch 8470	Ch 8350 – Ch 8470	Ch 8350 – Ch 8470	Ch 8350 – Ch 8470	Ch 8350 – Ch 8470	South Portal
	Ch 10310 – Ch 10350	Ch 10250 – Ch 10330	Ch 10250 – Ch 10390	Ch 10250 – Ch 10410	Ch 10250 – Ch 10410	Northwood Portal
	Ch 11220 – Ch 11330	Ch 11220 – Ch 11330	Ch 11220 – Ch 11330	Ch 11220 – Ch 11330	CH 11220 – Ch 11330	Ballymun Station
	Ch 12160 – Ch 12300	Ch 12170 – Ch 12330	Ch 12170 – Ch 12300	Ch 12160 – Ch 12300	Ch 12160 – Ch 12300	Collins Avenue Station
Ch 12790 - Ch 12820	Ch 12790 – Ch 12830	Ch 12790 – Ch 12840	Ch 12790 – Ch 12840	Ch 12800 – Ch 12830	Ch 12790 – Ch 12820	Albert College Shaft
Ch 13880 – Ch 13920	Ch 13760 – Ch 13920	Ch 13760 – Ch 13920	Ch 13760 – Ch 13920	Ch 13760 – Ch 13920	Ch 13760 – Ch 13880	Griffith Park Station
	Ch 13980 – Ch 14050	Ch 13980 – Ch 14040	Ch 14020 – Ch 14030			
	Ch 14860 – Ch 14930	Ch 14860 – Ch 14930	Ch 14830 – Ch 14930	Ch 14830 – Ch 14930	CH 14830 – Ch 14930	Glasnevin Station
	Ch 15590 – Ch 15690	Ch 15590 – Ch 15690	Ch 15590 – Ch 15690	Ch 15590 – Ch 15690	CH 15590 – Ch 15690	Mater Station
Ch 16720 – Ch 16740	Ch 16600 – Ch 16740	Ch 16600 – Ch 16710	Ch 16600 – Ch 16740	Ch 16600 – Ch 16740	CH 16600 – Ch 16740	O'Connell Station
Ch 17160 – Ch 17210	Ch 17160 – Ch 17220	Ch 17160 – Ch 17220	Ch 17160 – Ch 17220	CH 17160 – Ch 17220	Ch 17170 – Ch 17200	River Liffey
	Ch 17390 – Ch 17430	Ch 17380 – Ch 17460	Ch 17340 – Ch 17460	Ch 17340 – Ch 17460	CH 17340 – Ch 17460	Tara Station
Ch 18380	Ch 18380 – Ch 18510	Ch 18380 – Ch 18510	Ch 18380 – Ch 18510	CH 18380 – Ch 18510	Ch 18380 – Ch 18510	St Stephens Green Station
Ch 19280 – Ch 19400	Ch 19260 – Ch 19400	Ch 19260 – Ch 19400	Ch 19260 – Ch 19400	Ch 19260 – Ch 19400	Ch 19260 – Ch 19400	Charlemont Station

Table 5-4: Result of Refined Phase 2a Building Damage Assessment – 'additional' buildings

Ref	Associated Building	Chainage	Description	Estimated Height (m)	Number of Floors	Length (m)	Category of Damage	Listed/sensitive Structure? (Y/N)	Continue to next assessment phase (Y/N)	Comments
AB-01										Already demolished
AB-02	B-126a	11660	School - Scoil an Seachtar Laoch	5.0	2	51.3	1 (Very Slight)	N	N	Damage category 2 or below
AB-03	B-125a	11980	Residential	6.0	2	12.1	0 (Negligible)	N	N	Damage category 2 or below
AB-04	B-125b	12000	Residential	6.0	2	13.6	0 (Negligible)	N	N	Damage category 2 or below
AB-05	B-125c	12020	Residential	6.0	2	13.1	0 (Negligible)	N	N	Damage category 2 or below
AB-06	B-124a	12100	Residential	6.0	2	14.9	0 (Negligible)	N	N	Damage category 2 or below
AB-07	B-124b	12120	Residential	6.0	2	16.1	1 (Very Slight)	N	N	Damage category 2 or below
AB-08	B-124c	12130	Residential	6.0	2	12.1	1 (Very Slight)	N	N	Damage category 2 or below
AB-09	B-124d	12290	Residential	6.0	2	55.8	2 (Slight)	N	Y	Damage category 2 or below Case A (refer to section 4.1)
AB-10	B-124e	12330	Community Hall	6.0	2	33.1	2 (Slight)	N	N	Damage category 2 or below
AB-11	B-142a	13970	Residential	6.0	2	15.2	3 (Moderate)	N	Y	Damage category 3
AB-12	B-142b	13930	Residential	6.0	2	14.3	1 (Very Slight)	N	N	Damage category 2 or below
AB-13	B-160a	14010	Residential	6.0	2	29.5	3 (Moderate)	N	Y	Damage category 3
AB-14	B-160b	14040	Residential	6.0	2	25.6	2 (Slight)	N	N	Damage category 3 or above
AB-15	B-119a	14700	Residential	6.0	2	11.4	1 (Very Slight)	N	N	Damage category 2 or below
AB-16	B-121a	14720	Residential / Retail	6.0	2	12.0	0 (Negligible)	N	N	Damage category 2 or below
AB-18	B-121c	14740	Residential	9.0	3	22.9	0 (Negligible)	N	N	Damage category 2 or below
AB-19	B-157a	14800	Residential	9.0	3	28.9	1 (Very Slight)	N	Y	Damage category 2 or below Case A (refer to section 4.1)
AB-20	B-157b	14800	Residential	6.0	2	32.8	0 (Negligible)	N	Y	Damage category 2 or below Case A (refer to section 4.1)
AB-21	B-118a	14960	Residential	9.0	3	27.8	0 (Negligible)	N	N	Damage category 2 or below
AB-22	B-108a	15410	Residential	9.0	3	26.4	0 (Negligible)	N	N	Damage category 2 or below
AB-23	B-106a	15440	Residential	6.0	2	51.2	0 (Negligible)	N	N	Damage category 2 or below
AB-24	B-105a	15470	Residential	6.0	2	63.3	1 (Very Slight)	N	N	Damage category 2 or below
AB-25	B-105b	15520	Residential	5.0	2	20.9	0 (Negligible)	N	N	Damage category 2 or below
AB-28	B-89a	16300	Residential / Hall / Entertainment	12.0	4	63.6	1 (Very Slight)	N	N	Damage category 2 or below
AB-29	B-198a	16800	Residential / Retail	12.0	4	24.8	1 (Very Slight)	N	N	Damage category 2 or below
AB-30	B-67a	16830	Commercial – Central Post Office	9.0	3	19.2	2 (Slight)	N	N	Damage category 2 or below
AB-31	B-241a	17010	Retail	12.0	4	26.5	1 (Very Slight)	N	N	Damage category 2 or below
AB-32	B-57a	17260	Government	6.0	2	25.6	1 (Very Slight)	N	N	Damage category 2 or below
AB-33	B-50a	17540	Commercial	12.0	4	29.1	0 (Negligible)	N	N	Damage category 2 or below
AB-34	B-42a	17640	Residential / Retail	9.0	3	24.6	1 (Very Slight)	N	N	Damage category 2 or below

Ref	Associated Building	Chainage	Description	Estimated Height (m)	Number of Floors	Length (m)	Category of Damage	Listed/sensitive Structure? (Y/N)	Continue to next assessment phase (Y/N)	Comments
AB-35	B-31a	17930	Residential / Retail	12.0	4	25.4	0 (Negligible)	N	N	Damage category 2 or below
AB-36	B-30a	17940	Residential / Retail	12.0	4	8.8	0 (Negligible)	N	N	Damage category 2 or below
AB-37	B-52a	18700	Commercial	15.0	5	24.6	0 (Negligible)	N	N	Damage category 2 or below
AB-38	B-55a	18960	Commercial	12.0	4	18.5	0 (Negligible)	N	N	Damage category 2 or below
AB-39	B-147a	19000	Commercial	12.0	4	46.5	1 (Very Slight)	N	N	Damage category 2 or below
AB-40	B-149a	19200	Residential	9.0	3	17.7	1 (Very Slight)	N	N	Damage category 2 or below
AB-41	-	2300	Residential	3.0	1	19.0	N/A	N	N	Assume to be demolished
AB-42	B163a	5050	Residential	4.0	1	14.7	2 (slight)	N	N	Damage category 2 or below
AB-43	B163a	5150	Residential	3.0	1	13.6	2 (slight)	N	N	Damage category 2 or below
AB-44	B-124a	12250	Residential	5.0	2	11.6	2 (slight)	N	N	Damage category 2 or below
AB-45	B-143a	13800	Residential	5.0	2	12.2	2 (slight)	N	N	Damage category 2 or below
AB-46	B-143a	13850	Residential	5.0	2	15.9	2 (slight)	N	N	Damage category 2 or below
AB-47	B-103a	15600	Residential	5.0	2	11.7	2 (slight)	N	Y	Damage category 2 or below Case A (refer to section 4.1)
AB-48	B-237a	15700	Residential	3.0	1	25.8	2 (slight)	N	N	Damage category 2 or below
AB-49	B-101a	15720	Residential	10.0	4	19.2	1 (Very Slight)	N	N	Damage category 2 or below
AB-50	B-76a	16600	Commercial	20.0	7	75.0	2 (slight)	N	Y	Damage category 2 or below Case A (refer to section 4.1)
AB-51	B-35a	17880	Sports Facility	5.0	2	18.7	0 (Negligible)	N	N	Damage category 2 or below
AB-52	B-32a	17900	Sports Facility	6.0	2	51.3	0 (Negligible)	N	N	Damage category 2 or below

6. Impact Assessment of Bridges and Other Assets

6.1 General

In this section, an appraisal of the potential impact of MetroLink construction generated ground movements on other assets is provided, covering:

- Existing bridges
- Railways
- Luas
- Major roads
- Airport assets

Utilities and services are excluded from this assessment and are covered by a separate assessment due to there being over 50,000 utilities to be considered along the Metrolink route.

6.2 Proposed Developments

No new developments that are proposed to be constructed within the MetroLink ground movement zone of influence have been identified. However, there is the potential for planned future developments that are not yet currently visible to be in place or under construction by the time MetroLink construction commences and therefore these will need to be taken account of by the MetroLink B&B Contractor.

6.3 Location of Bridges and Other Assets

The reference number and locations of existing bridges and other assets that could potentially be impacted by MetroLink construction generated ground movements are identified by Table 6.1. The locations of these structures and other assets are also marked on the Phase 1 greenfield settlement contours provided in Appendix C.

Table 6-1: List of Bridges and Other Assets Identified Within The MetroLink Settlement Zone Of Influence

Structure Ref	Chainage	Description	Distance from tunnel centreline
ST-1	8+320	Old Airport Road – airport perimeter roads, landside, and airside	0m
ST-2	12+900	Ballymun Road Petrol Station	26.6m
ST-3	13+900	St Mobhi Road Bridge – single span road bridge over the Tolka River	17.7m
ST-4	14+890	Road bridge – single span road bridge over railway	0m
ST-5	14+940	Road bridge – single span road bridge over railway	0m
ST-5a	14+950	Road bridge – single span road bridge over canal	0m

Structure Ref	Chainage	Description	Distance from tunnel centreline
ST-5b	14+950	Cross Guns Quay Canal Lock – walls and gates	0m
ST-6	16+900	O' Connell Street – Jim Larkin Statue	0m
ST-7	17+120	Rosie Hackett Bridge – single span road/tram bridge over River Liffey	9.1m
ST-8	17+380	Bridge over Pootberg Street corner with Luke Street – single span rail over road bridge, cast iron / steel construction carrying railway and platforms of Tara Station	22.8m
ST-9	17+500	Bridge over Townsend Street - single span rail over road bridge, steel construction	23.1m
ST-10	17+580	Bridge Over Shaw Street - single span rail over road bridge, steel / cast iron construction, large skew	25.4m
ST-11	19+420	Bridge over Dartmouth Road - single span rail over road bridge, steel construction	7.7m
ST-12	19+520	Bridge over Northbrook Road - single span rail over road bridge, steel construction	9.4m to main tunnel, 3.5m to escape gallery
ST-13	19+780	Bridge over Ranelagn Road - single span rail over road bridge, steel construction	24.9m
ST-14	19+943	Bridge over Cullenswood Road - single span rail over road bridge, steel construction	Outside 1mm contour
ST-15	19+350 – 19+750	Embankment carrying Luas, masonry faced circa 4-5m in height, interspersed with ST-11 to ST-14	Varies between 0 and 35m

6.4 Assessment of Existing Bridges

The ground movement impact assessment undertaken, assumes, unless stated otherwise, the bridge decks are simply supported on bearings, with the bridge abutments resting on shallow foundations, and therefore the assessment conservatively assumes that the bridge abutments will be more susceptible to ground movements, and the bridge deck supports will be more likely to require additional mitigation measures should they be exposed to differential movement. The assessment also assumes, reasonably, that the existing bridges are in sound structural condition and can accommodate additional movements of at least 50% of the below-mentioned limits applicable for new bridge foundation designs.

The following typical limits for allowable movements (SLS) are reported in Table 52.6 of the ICE Manual of Geotechnical Engineering [Ref. 14] for new bridge foundation designs:

- Maximum settlement: 60mm
- Horizontal displacement: 40mm
- Angular distortion between 1:250 and 1:500 depending upon the bridge deck characteristics and articulation arrangements

These limits are applicable for new bridge design, and not necessarily as additional movements that can be accommodated by existing bridges. However, it is accepted practice that these values can be applied when assessing the impacts of ground movements on existing bridges.

At the detailed assessment stage, detailed structural condition surveys of the bridges will inform the detailed damage assessment to verify the findings of this conservative preliminary ground movement impact assessment. The allowable displacement limits determined during this assessment will be agreed with the asset owners, thereafter, informing agreement on any necessary intervention measures.

St Mobhi Road Bridge over the Tolka River (ST-3)

St Mobhi is a single span (approximate span of 15m) road bridge over the Tolka River. The settlement contours in the surrounding area of the bridge are shown in Figure 6-1. The south end of the bridge is predicted to settle 5-8mm, and the north end of the bridge is predicted to settle 25-30mm. Based on these values, the total settlement at the supports is not a concern for this single span bridge; further, the differential settlement gradient across the supports is anticipated to be less than 1 in 600 across the bridge deck. No intervention measures are therefore anticipated for this bridge.

Figure 6-1: Settlement Contours Around St Mobhi Road Bridge (ST-3)

Road Bridge over the Railway (ST-4, ST-5 and ST-5a)

ST-4 (approximately 15m span) and ST-5 (approximately 12m span) are single span road bridges over the railway. ST-5a is also a single span (approximate span 16m) steel road bridge spanning the canal. The settlement contours in the surrounding area of the bridges are shown in Figure 6-2.

The south and north ends of ST-4 and ST-5 are predicted to settle 50-70mm. The south end of the ST-5a is predicted to settle 30mm, and the north end of the bridge is predicted to settle 45mm. Based on these values, the total settlement at the supports is a concern for these single span bridges due to the closeness of the bridges to the Glasnevin station box excavation. The transverse differential settlement across the width of these bridges (along east-west direction) is expected to be in the order of 20mm. Mitigation works will be required for each.

A potential solution to tackle this issue is to support the bridge deck on temporary bearings/jacks during the construction of Glasnevin Station and adjust the bearing levels based on the actual settlement experienced and recorded by monitoring instrumentation. The requirement for such intervention will need to be carefully reviewed at the detailed design stage as part of the Phase 2b assessment taking account of any updated survey information, detail design development (increased design maturity) and finalisation of the D&B contractor's construction methodology and planning.

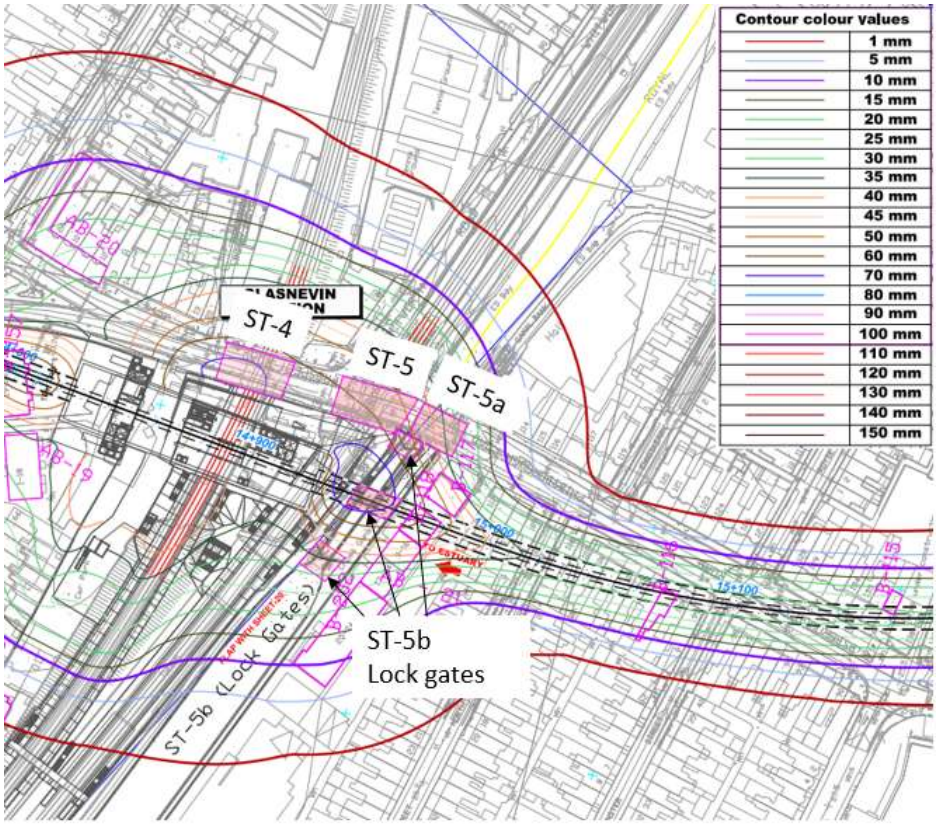


Figure 6-2: Settlement Contours Around Bridges ST-4, ST-5, ST5a and ST-5b

Rosie Hackett Bridge – Road/Tram bridge over River Liffey (ST-7)

Rosie Hackett Bridge is a single span road/tram bridge (approximate span 50m) over the River Liffey supported on pile foundations. The settlement contours in the surrounding area of the bridge are shown in Figure 6-3. The south-west end of the bridge is located outside the 1 mm settlement contour; the north-east end of the bridge is predicted to settle less than 10mm. Based on the above, no mitigation measures are proposed for this bridge.

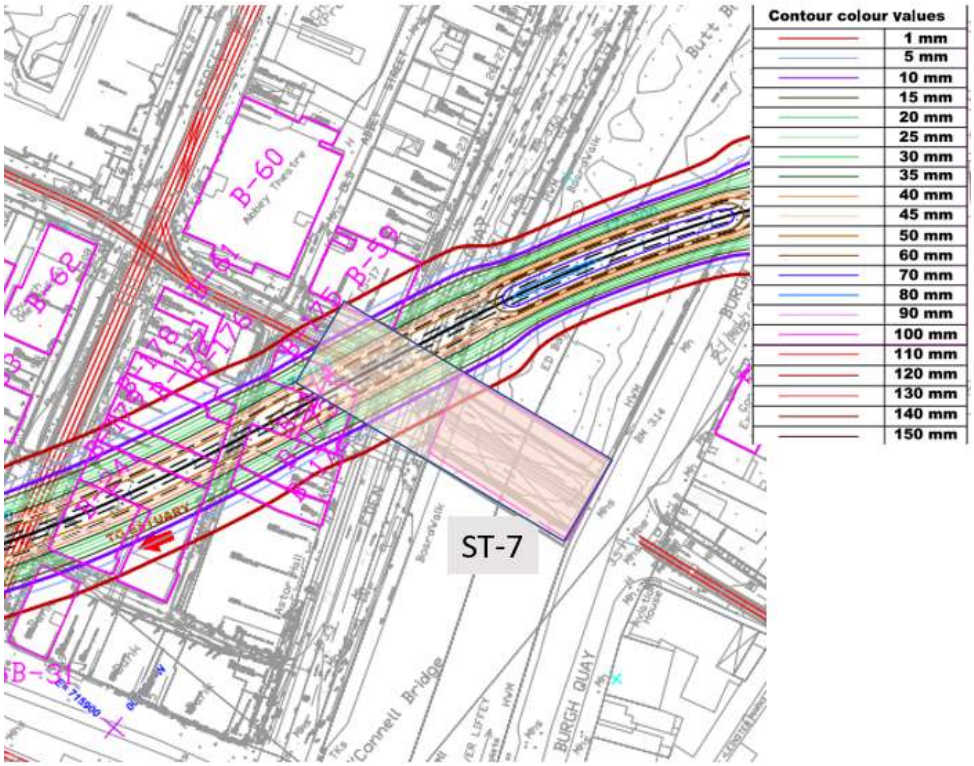


Figure 6-3: Settlement Contours Around Rosie Hackett Bridge (ST-7)

Rail bridges Near Tara Station (ST-8, ST-9, and ST-10)

ST-8 (approximate span 36m) and ST-9 (approximate span 18m) are single span railway bridges over the roads. Each are of steel construction. The settlement contours in the surrounding area of the bridges are shown in Figure 6-4.

The north end of ST-8 is predicted to settle 5mm. The south end of the bridge is predicted to settle 20-30mm. Based on these values, the total settlement at the supports is not a concern for this single span bridge. The transverse differential settlement across the supports at the south end (of the order of 15mm) is expected to cause moderate torsional effects on the bridge deck, although steel construction has some resilience to absorb such effects without developing undue stress concentrations. No intervention measures are therefore anticipated to be required.

The south end of ST-9 is located almost outside of the 1mm contour. The north end of the bridge is predicted to settle 10-15mm. Based on these values, the total settlement at the supports is not a concern

for this single span bridge. The transverse differential settlement across the supports at the north end (5-10mm) is expected to cause slight torsional effects for the bridge deck. Considering steel construction, the impact due to torsional effects is unlikely to be significant. No intervention measures are therefore anticipated to be required.

ST-10 is located just outside the 1mm contour, and no intervention measures are required for this bridge.

Figure 6-4: Settlement Contours Around Tara Station Bridges (ST-8, ST-9 & ST-10)

Bridges Carrying Luas Line Near Charlemont Station (ST-11, ST-12, ST-13, and ST-14)

ST-11 (approximate span 15m) and ST-12 (approximate span 13m) are single span bridges over the road with steel construction carrying the Luas line near Charlemont Station. The settlement contours in the surrounding area of the bridges are shown in Figure 6-5.

The settlement at the north support of ST-11 is predicted to be of the order of 15-20mm. At the south end it is predicted to be of the order of 20-30mm. Based on these values, the total settlement at the supports is not a major concern for this single span bridge. The transverse differential settlement across the supports is expected to be of the order of 5-10mm and considering the steel construction it is not anticipated to cause significant torsional impacts to the bridge deck. No intervention measures are therefore anticipated to be required.

The settlements at the corners of ST-12 are predicted to be of the order of 15-20mm. Based on these values, the total settlement at the supports is not a major concern for this single span bridge. Further, the transverse differential settlement across the supports is expected to be of the order of 5-10mm and considering steel construction it is not anticipated to cause significant torsional effects on the bridge deck. No intervention measures are therefore anticipated to be required.

ST-13 and ST-14 are located just outside the 1mm contour and therefore no intervention measures are necessary for these bridges.

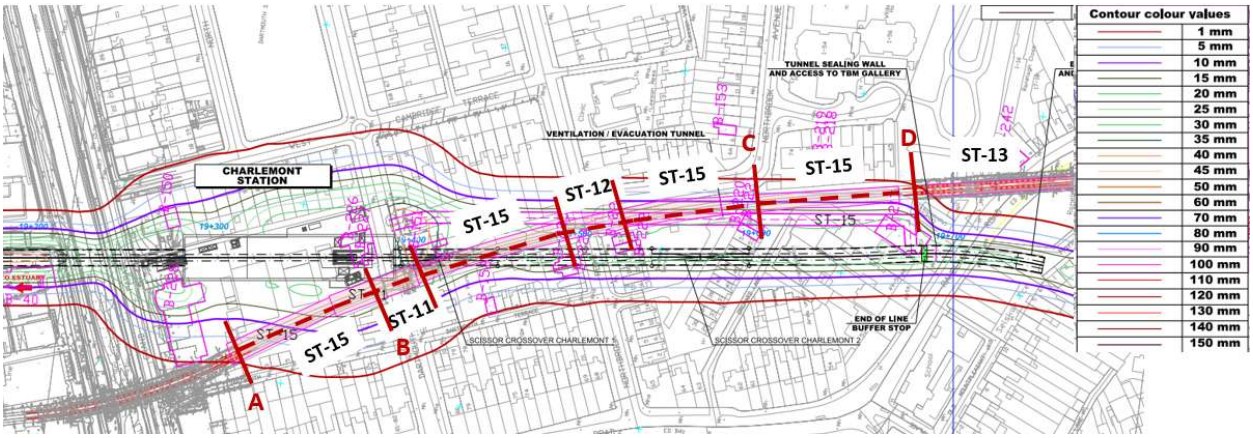


Figure 6-5: Settlement Contours Around Charlemont Station Bridges (ST-11 and ST-12)

6.5 Iarnród Éireann Lines

The Iarnród Éireann Maynooth and Cork lines will cross over the proposed MetroLink Glasnevin Station and will be designed as an integral part of the MetroLink station structure. For this reason, these lines are not considered by this ground movement impact assessment.

Iarnród Éireann lines supported on bridges ST-8, ST-9 and ST-10 also pass close to the proposed MetroLink Tara Station as shown by Figure 6.4. The predicted settlement profile along line A-B-C (in Figure 6-4) is shown in Figure 6-6. The maximum differential settlement gradient along the railway is not predicted to exceed 1 in 1000. This is sufficiently low, considering the 1 in 250 limiting values specified by UK Network Rail standard [Ref. 15] for 'no mandated' action. However, total settlement of 25mm is slightly higher than the 23mm limiting value specified by the UK Network Rail standard and therefore intervention may be required to adjust the track levels during the construction of Tara Station based on the actual settlement experienced and recorded by monitoring instrumentation.

An appropriate instrumentation and monitoring strategy with agreed movement trigger levels will be developed and agreed with Iarnród Éireann to ensure ground movements are mitigated by controlled adjustment of the track levels.

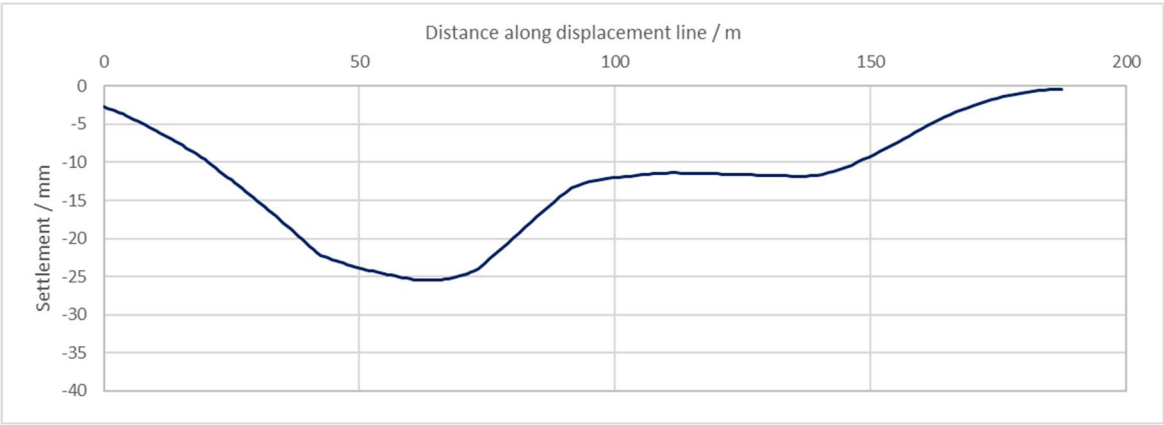


Figure 6-6: Settlement Profile along the Railway (Line A-B-C in Figure 6-4)

6.6 Luas Line

The settlement trough is predicted to impact Luas lines in two zones where the line crosses the proposed route. The approximate chainages covering these zones are:

Zone L1: City centre Ch 16+800 to Ch 17+200

Zone L2: South of Charlemont Ch 19+300 to Ch 19+800.

Zone L1 City Centre

Both the Luas Green Line and the Luas Red Line cross the proposed MetroLink route as shown in Figure 6-7. The greenfield settlement profiles predicted along lines AB (Luas Green Line), BC (Luas Red Line) and CD (Luas Green Line) are shown in Figures 6-8a, 6.8b and 6.8c respectively.

The maximum differential gradient along line AB will be less than 1 in 1000 and will not be an issue. The maximum differential gradient along lines BC and CD will be in the order of 1 in 240. This is based on the Phase 1 greenfield settlement contours and will be of the order of 1 in 350 if refined Phase 2a volume loss values are adopted for the tunnelling works. Considering that the tramways are relatively flexible in a longitudinal direction, no intervention is anticipated.

Figure 6-7: Zones of Luas Line Crossing the MetroLink Route (Zone L1)

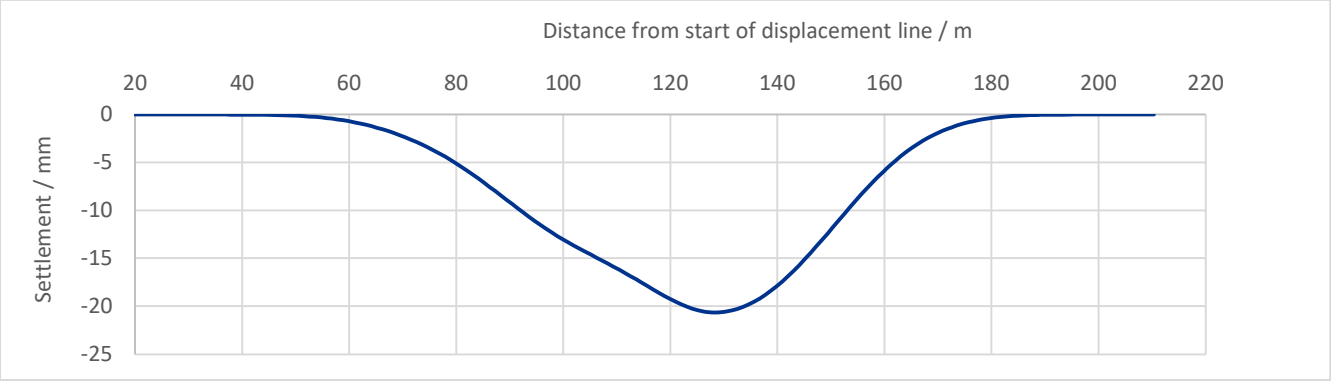


Figure 6-8a: Settlement Profile Along Segment AB of Luas Line

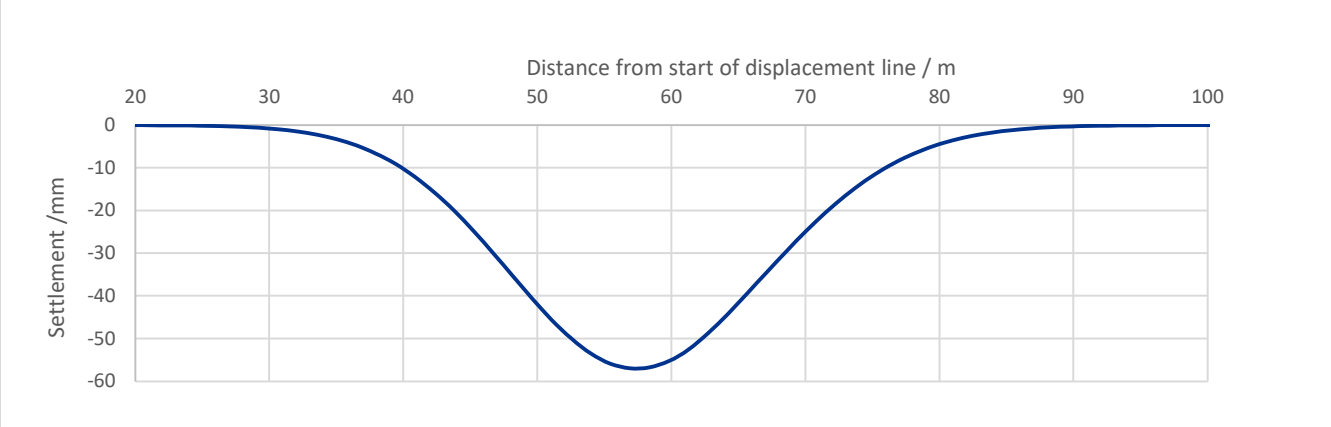


Figure 6-8b: Settlement Profile Along Segment BC of Luas Line

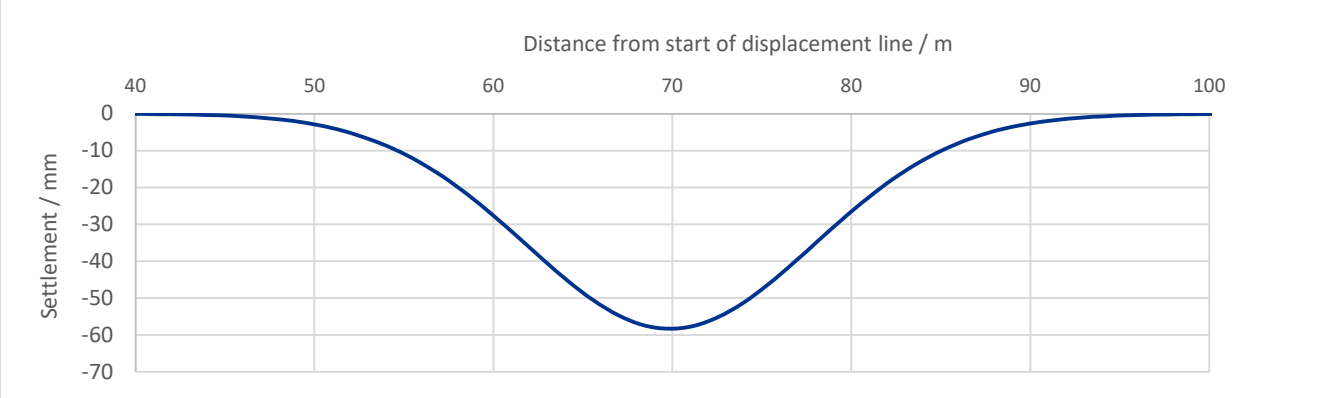


Figure 6-8c: Settlement Profile Along Segment CD of Luas Line

Zone L2 South of Charlemont

In this zone, the Luas line is supported on embankment ST-15 (refer Table 6-1) intersected by short span bridges (ST-11, ST-12, and ST-13) as shown in Figure 6-5. The greenfield settlement profiles at ground level along AB, BC and CD are shown in Figure 6-9.

The maximum differential gradient along this section will be less than 1 in 2000 and therefore no intervention is anticipated.

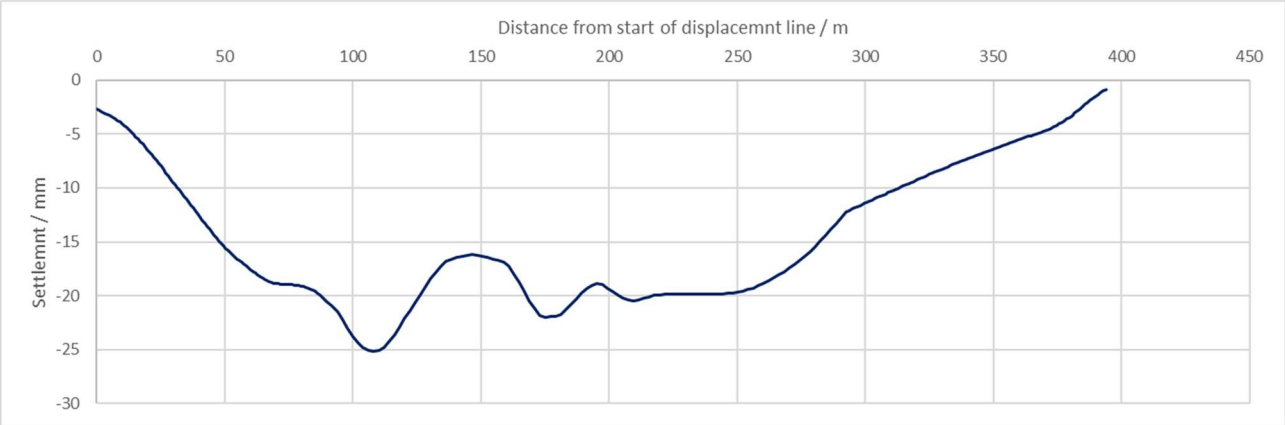


Figure 6-9: Settlement Profile Along Segment ST-15 Embankment

6.7 Existing Major Roads

The MetroLink alignment crosses the Old Airport Road (ST-1 in Table 6-1). Figure 6-10 shows the predicted Phase 1 settlement contours at this location, and the corresponding settlement trough developed along the centreline of the road is presented in Figure 6-11. The calculated maximum settlement will be approximately 60mm, with a resulting differential settlement gradient less than 1 in 450. Based on these values, the impact on the road is assessed to be extremely low since the resulting differential settlement gradient will be lower than the standard maintenance tolerance of 1 in 300.

A similar process has been applied to other selected roads crossing the MetroLink alignment. The calculated greenfield settlement troughs are presented in Figure 6-12. The peak settlement typically varies between 20 and 70mm based on the Phase 1 greenfield settlement contours. However, in areas away from the station boxes and cuttings, the peak settlement values are unlikely to exceed 50mm, and the differential settlement gradients are unlikely to exceed 1 in 300 when refined Phase 2a volume loss values are adopted for the tunnelling works; no issues are therefore anticipated for roads located away from the station boxes and retained cuttings.

In a few instances, roads close to the proposed station boxes and retained cuttings are likely to experience maximum settlements greater than 50mm (based on the Phase 1 assessment) and the differential settlement gradients could exceed the threshold limit of 1 in 300. For these roads there is a possibility of surface cracking occurring during MetroLink construction, and localised surface repairs may therefore be required to maintain the integrity of the road surface structure. Roads will need to be monitored and inspected regularly during the construction period, and maintenance and repair of the subbase and surface undertaken to maintain the stability and suitability of the road surface. These requirements will be applicable to roads aligned parallel to the proposed MetroLink station boxes and

retained cuttings within a distance equal to the depth of superficial material measured from the perimeter of the retaining wall constructed. Within this zone there will be an increased risk of longitudinal cracks developing in the road surface.

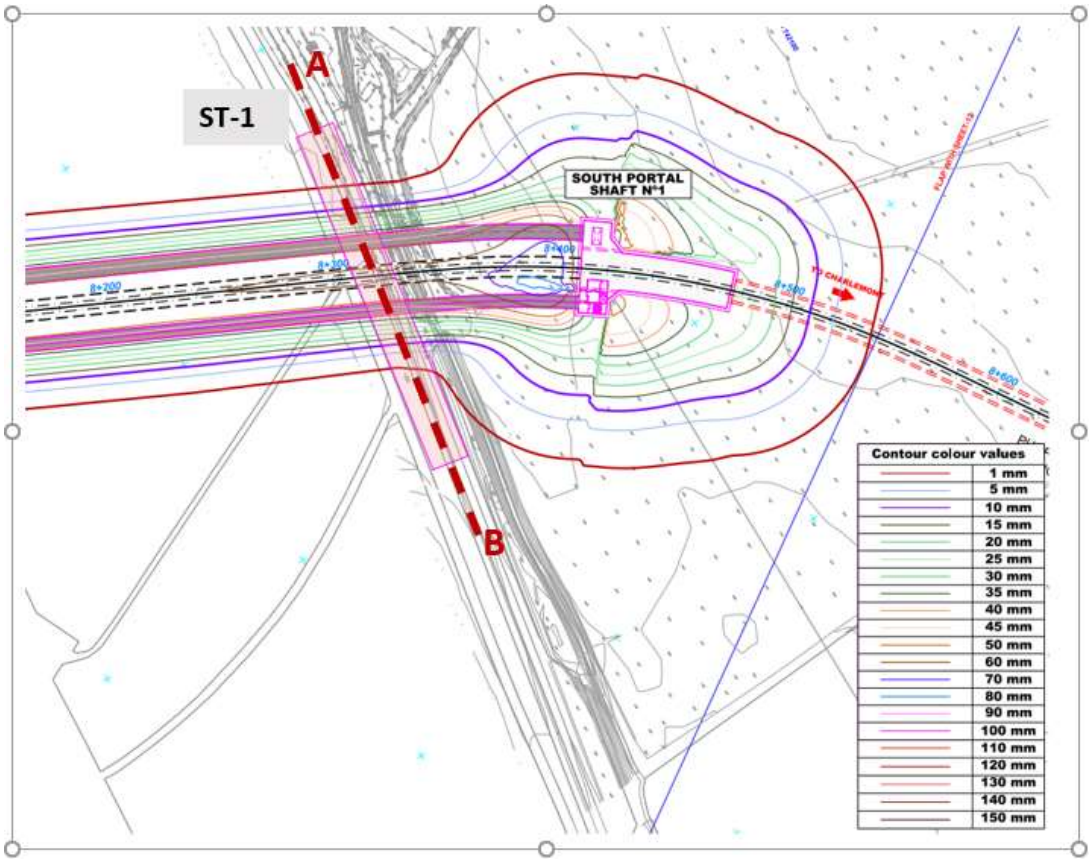


Figure 6-10: Settlement Contours Around The Old Airport Road (ST-1)

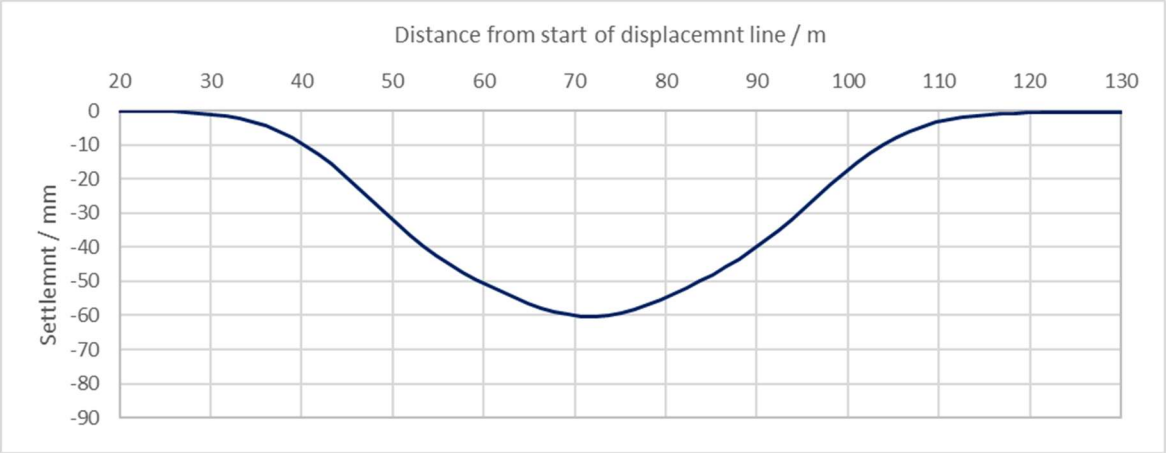


Figure 6-11: Settlement Profile Along The Old Airport Road (ST-1)

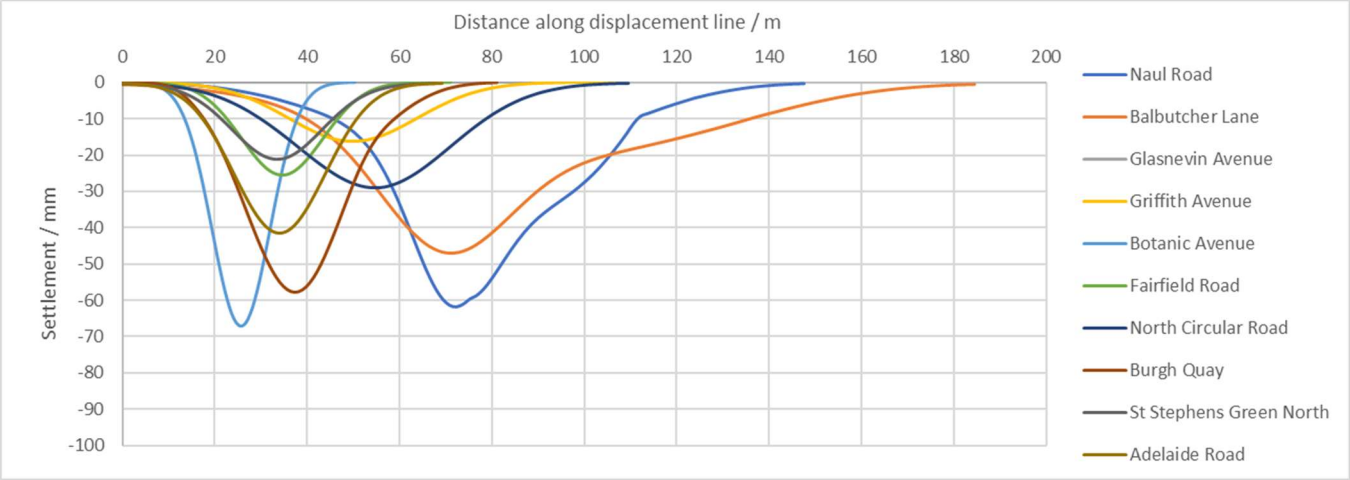


Figure 6-12: Typical Greenfield Settlement Troughs Along Tthe Roads Crossing The MetroLink Route

6.8 Airport Infrastructure

In the area of Dublin Airport, greenfield settlement profiles are provided for the following three cross sections.

- Section A-A: perpendicular to the tunnel alignment, through the main tunnel only (Figure 6-13a)
- Section B-B: through the main tunnel and the ventilation tunnel (Figure 6-13b)
- Section C-C: through the main tunnel, the ventilation tunnel, and the emergency evacuation tunnel (Figure 6-13b)

The greenfield settlement profiles for all three cross sections are presented in Figure 6-14. The maximum settlements above the tunnel alignment for Sections A-A, B-B and C-C are predicted to be 32mm, 50mm and 60mm respectively. The differential settlement gradients in each instance are unlikely to exceed 1 in 450.

The European Aviation Safety Agency Document CS-ADR-DSN (Certification Specifications and Guidance Material for Aerodromes Design, Issue 4, 8 Dec 2017) specifies that longitudinal slopes on taxiways should not exceed 1.5% (CS ADR-DSN.D.265) and longitudinal slope changes on taxiways should not exceed 1% per 30m (CS ADR-DSN.D.270). Assuming that the taxiway is currently flat, the maximum change in the slope due to the tunnelling induced settlement (0.22%) is well within the allowable limit. Further, the predicted longitudinal slope change is approximately one-third of the allowable limits, see Figure 6-14. No mitigation work is therefore anticipated as being required for the aircraft stands and taxiway.

It is anticipated that movement monitoring instrumentation and survey points will be installed across the areas that could potentially be impacted by construction generated ground movements to monitor any movement of the concrete pavement and any movement of the subgrade under the concrete pavement. Monitoring proposals will be developed by the D&B contractor and with DAA. Data collected will verify actual ground movements and confirm the relationship between subgrade settlement and pavement settlement.

The impact of construction generated ground movements on airport buildings has been assessed as Damage Category 2 or less (see Table 5-2).

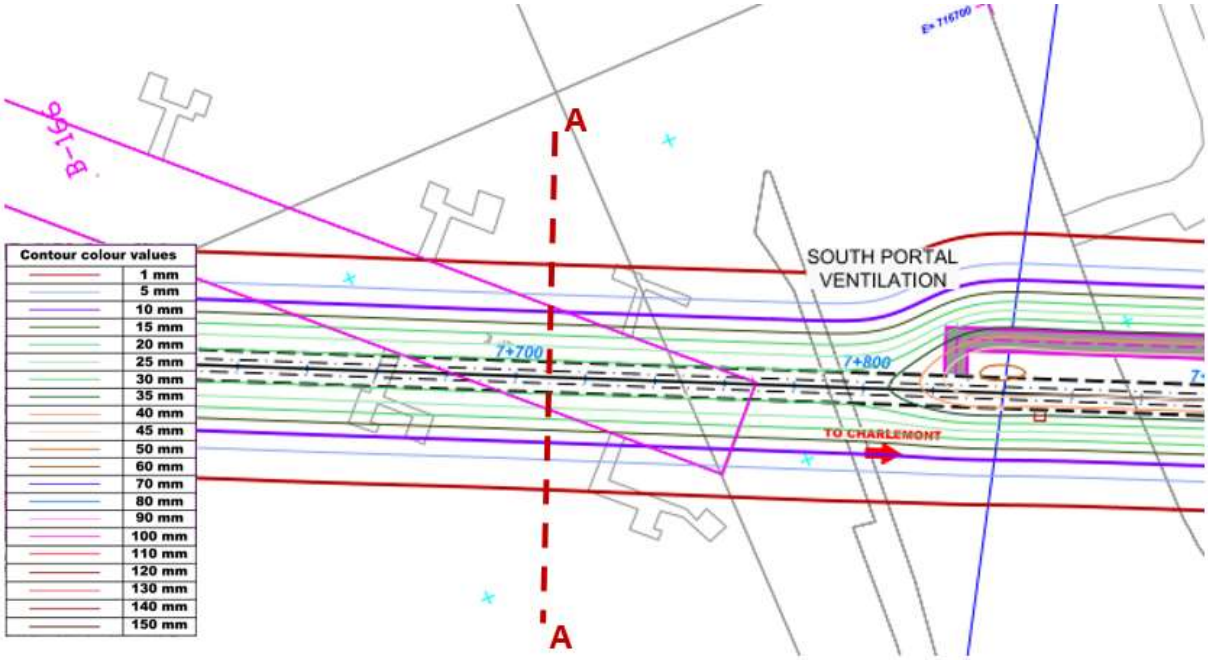


Figure 6-13a: Settlement Contours Around the Single (main) Tunnel Zone

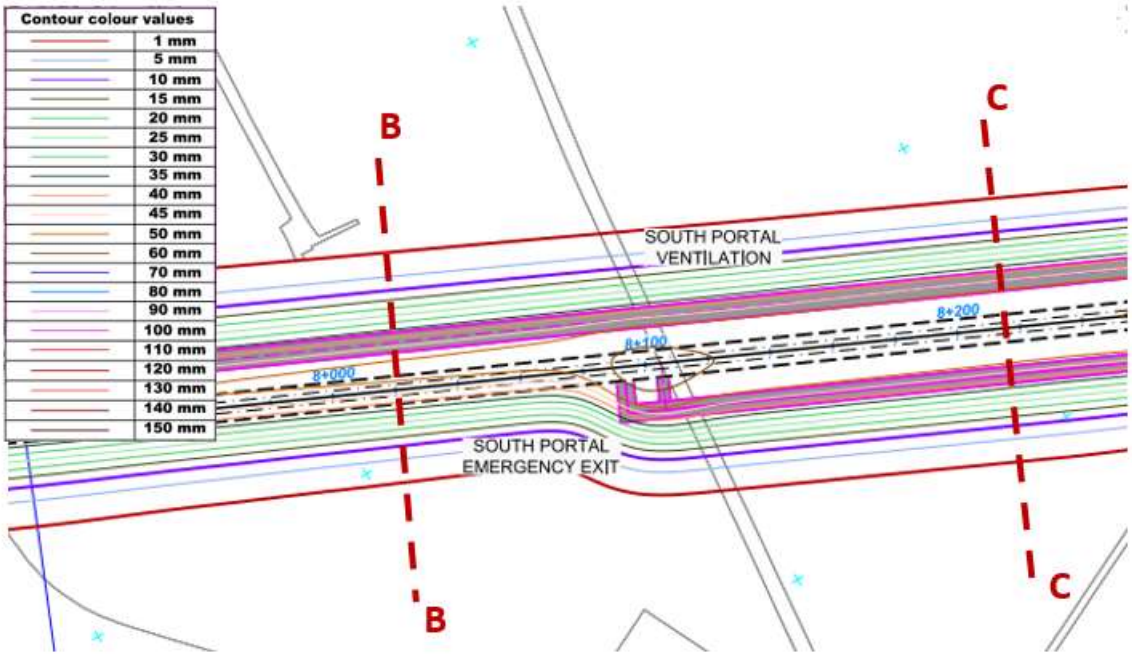


Figure 6-13b: Settlement Contours Around the Twin and Triple Tunnel Zone

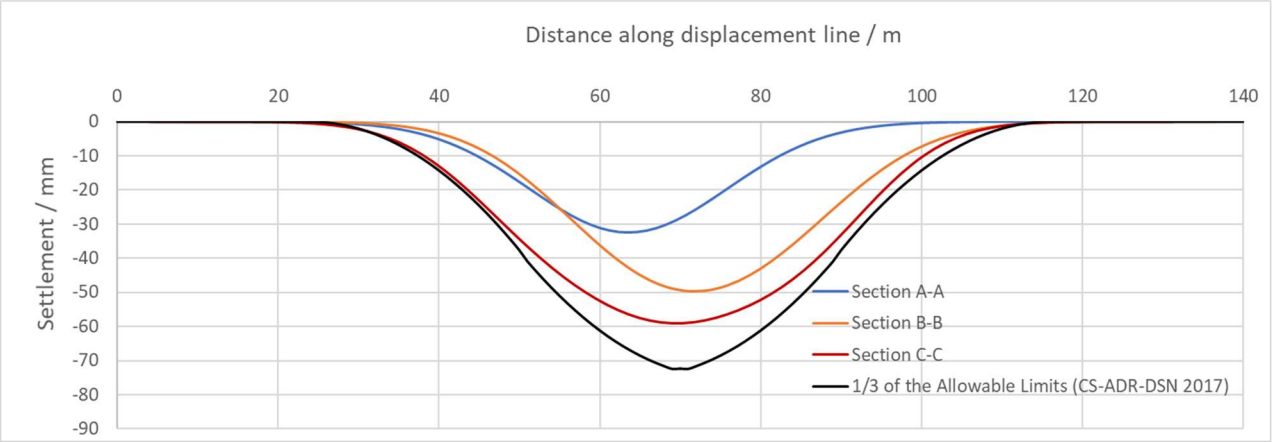


Figure 6-14: Greenfield Settlement Troughs in the Airport Area

6.9 Other

Ballymun Road Petrol Station (ST2)

The settlement contours in the surrounding area of the Ballymun Road petrol station (ST-2) are shown in Figure 6-15. The petrol station falls almost entirely outside of the 1mm contour and therefore no further assessment is required.

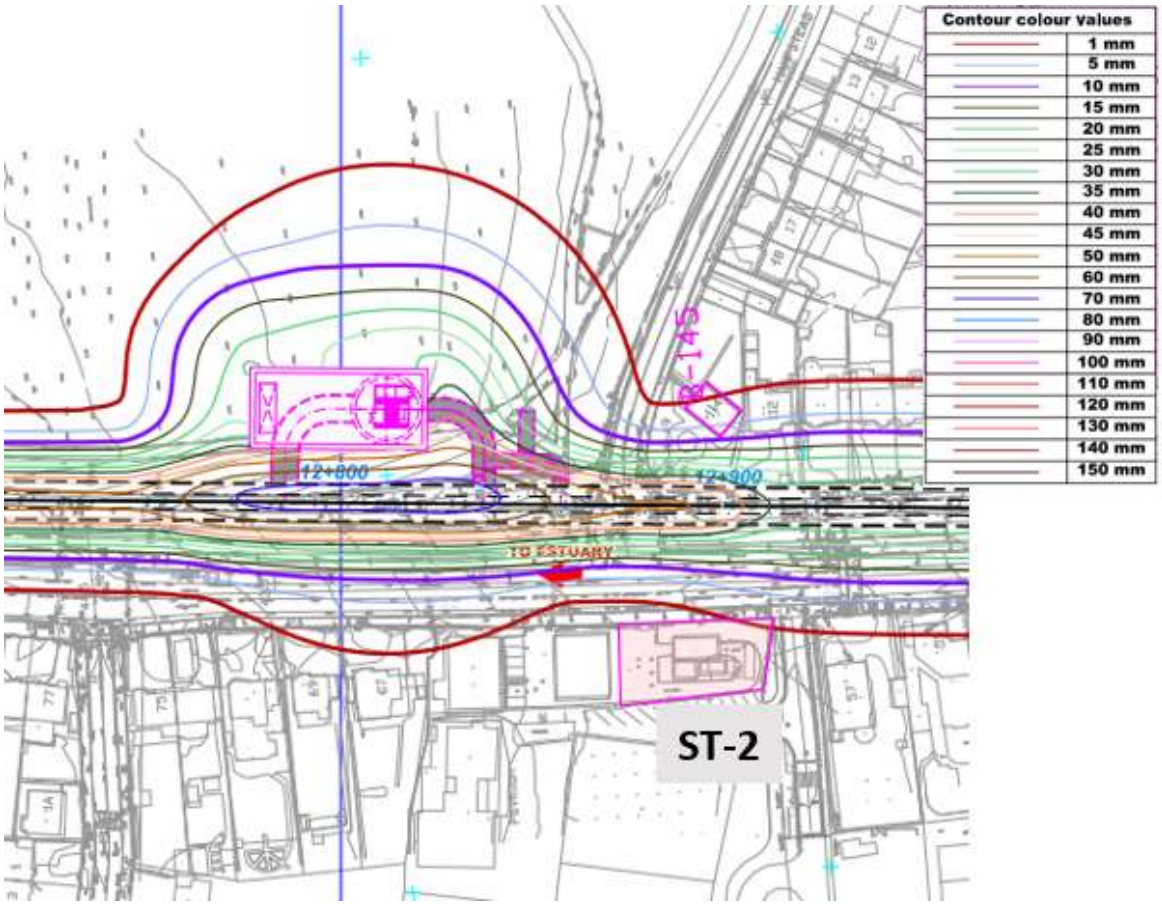


Figure 6-15: Settlement Contours Around Ballymun Road Petrol Station (ST-2)

O' Connell Street – Jim Larkin Statue (ST-6)

The settlement contours surrounding the Jim Larkin Statue (ST-6) are shown in Figure 6-7. The base of the structure has a small footprint and therefore the monument will settle as a rigid body without any measurable tilt. The overall settlement is predicted to be less than 25mm. No protection measures are therefore required.

Cross Guns Quay Canal Lock – walls and gates (ST-5b)

The predicted settlement contours in the area of the canal lock (ST-5b) are presented by Figure 6-2. The canal lock structures have a relatively small footprint and would normally have been considered as a single integrated structure. However, the middle gate is predicted to settle 70mm, and the gates either side are predicted to settle 35-50mm. Although these structures are not anticipated to undergo significant tilt, due to their relatively close position to the proposed MetroLink Glasnevin Station, there is a risk that jamming of the gates may occur due to relative movements on the vertical guide rail which could impede gate operations. It is therefore anticipated that the gates will need to be monitored to inform any necessary periodic gate adjustment in response to any movement experienced.

6.10 Summary

Table 6-2 summarises the results of the ground movement impact assessment of existing bridges and other assets, excluding utilities and services that are covered by a separate assessment due to there being over 50,000 utilities to be considered along the Metrolink route.

Table 6-2: Summary of Preliminary Assessment

Ref	Chainage	Description	Comments
ST-1	8+320	Old Airport Road	Differential settlement gradient less than 1 in 450. No further assessment required.
ST-2	12+860	Ballymun Road Petrol Station	Outside 1mm settlement contour. No further assessment required.
ST-3	13+900	St Mobhi Road Bridge	Single-span bridge on shallow foundations. No mitigation works anticipated.
ST-4	14+890	Road bridge	Single-span bridge on shallow foundations. Intervention in the form of adjustment to bearing levels of the bridge is likely to be required due to the close proximity of the proposed Glasnevin Station box excavation.
ST-5	14+940	Road bridge	Single-span bridge on shallow foundations. Intervention in the form of adjustment to bearing levels of the bridge is likely to be required due to the close proximity of the proposed Glasnevin station box excavation.
ST-5a	14+950	Road bridge	Single-span bridge on shallow foundations. Intervention in the form of adjustment to bearing levels of the bridge is likely to be required due to the close proximity of the proposed Glasnevin station box excavation.
ST-5b	14+950	Cross Guns Quay Canal Lock	Survey and adjustment of lock gates required..
ST-6	16+900	O' Connell Street – Jim Larkin Statue	Rigid structure. No further assessment required.
ST-7	17+120	Rosie Hackett Road Bridge	Single-span bridge supported on pile foundations. No mitigation works anticipated.
ST-8	17+380	Rail bridge over Pootberg Street corner with Lucke Street	Single-span bridge on shallow foundations. Invention in the form of adjustment to bearing levels of the bridge may be required due to the close proximity of the proposed Tara Station box excavation.
ST-9	17+500	Rail bridge over Townsend Street	Single-span bridge on shallow foundations. No mitigation works anticipated.
ST-10	17+580	Rail bridge Over Shaw Street	Outside 1mm settlement contour. No further assessment required.

Ref	Chainage	Description	Comments
ST-11	19+420	Luas Line bridge over Dartmouth Road	Single-span bridge on shallow foundations. Invention in the form of adjustment to bearing levels of the bridge might be required due to the close proximity to the proposed Charlemont station box excavation.
ST-12	19+520	Luas Line bridge over Northbrook Road	Single-span Luas Line bridge on shallow foundations. No mitigation works anticipated.
ST-13	19+780	Luas Line bridge over Ranelagn Road	Outside 1mm settlement contour. No further assessment required.
ST-14	19+943	Luas Line bridge over Cullenswood Road	Outside 1mm settlement contour. No further assessment required.
ST-15	19+300 to 19+800	Embankment carrying Luas Line	No intervention to Luas Line anticipated. Instrumentation & Monitoring strategy to be agreed with the Luas line operators.
Irish Rail Line	17+380 to 17+580	Irish Rail Line adjacent to Tara Station	Some intervention to adjust the rail levels is anticipated during the construction of Tara Station. Appropriate Instrumentation & Monitoring strategy to be agreed with the Irish Railway authorities.
Luas Line	16+800 to 17+200	Green Line and Red Line	No intervention of the Luas Line anticipated. Instrumentation & Monitoring strategy to be agreed with the Luas line Operators.
Airport Infrastructure		Airfield / Taxiway	No intervention to airport infrastructure anticipated. Appropriate Instrumentation & Monitoring strategy to be agreed with DAA.
Key Roads		Roads crossing above the MetroLink tunnel alignment or running close to the proposed station boxes or retained cuttings.	Minimal impact in general, except for roads close to the station boxes or retained cuttings that are currently predicted to experience Phase 1 greenfield peak settlements greater than 50mm. In these areas there exists a risk of surface cracking of the highway and therefore resurfacing and local patch repairs may be required, informed by a surface settlement monitoring and intervention strategy that will be agreed with the relevant highway authority.

7. Summary of Assessment and Recommendations

The industry standard three-phased approach (see Appendix D) has been carried out to assess the risk of damage to buildings from MetroLink construction generated ground movements.

The green-field settlement contours developed as part of the Phase 1 assessment are presented in Appendix C and are based on conservative volume loss assumptions for the tunnelling works.

All the buildings identified from the Phase 1 assessment have been subjected to a refined Phase 2a assessment for which the TBM tunnelling induced volume loss values have been refined (compared to that adopted for Phase 1 assessment) as follows:

- Tunnelling in superficial material (clay or granular material) or in rock with less than half the tunnel diameter rock cover: V_l = 1.0%
- Tunnelling in rock with at least half-a-tunnel diameter rock cover: V_l = 0.5%

For the non-TBM works, the volume loss values have been taken as 1.5 times the corresponding values adopted for the TBM works. The volume loss and trough width parameters adopted along the MetroLink route are tabulated in Table 5.1. For the station boxes and retained cuttings, the Phase 2a assessment is founded on the assumptions set out in the Key Assumptions Register, Appendix E.

As a part of the Preliminary Design, a representative sample of the buildings that could potentially be impacted by ground movements generated by MetroLink construction have been surveyed, termed as ‘representative’ buildings in this report. At the end of the Phase 2a assessment, all the ‘representative’ buildings have been determined to fall within Damage Category 2 or below, and therefore no mitigation works are anticipated for these buildings.

The Phase 2a assessment has been based on the final cumulative ground movements due to the combined effects of the tunnelling and all other excavation works. As part of the Phase 2b assessment, the detailed designer (for the D&B Contractor) will review and refine the Phase 2a assessment of these buildings and refine the assumptions based on updated information, the maturing design and the contractors finalised construction methodology and planning. In addition ‘special’ buildings (refer to Section 2.11 of the assessment methodology in Appendix D) shall be subject to a Phase 3 assessment. These buildings have been identified in Table 5-2 together with the Phase 2a assessment results.

This report concludes that the risk of any control or mitigation measures being required for the ‘representative’ buildings at the end of Phase 3 assessment is very low. However, provision, as a precaution, should be made at this time for ground treatment to protect the Carrolls Building (B-228) due to its close proximity (less than 2m) to the proposed excavation works associated with the Charlemont Station box construction.

In addition to the ‘representative’ buildings, more buildings have been identified for the Phase 2a assessment and these buildings are referred to as ‘additional’ buildings in this report (refer to Table 5-4). At the end of the refined Phase 2a assessment, except for two terrace blocks (AB11 & AB13), all of the ‘additional’ buildings fall within Damage Category 2 or below and therefore no protection works are anticipated for these buildings.

For the two terrace blocks which fall into Damage Category 3, it is likely that the detailed Phase 3 assessment will bring the damage category level to below Damage Category 2. If not, it is considered that post MetroLink construction, repair, together with an appropriate instrumentation and monitoring strategy, would be a more economical and practicable treatment strategy for these buildings rather than more disruptive and intrusive pre-construction protection measures.

Bridges ST-4, ST-5 and ST-5a (see Table 6-1) that are in close proximity of the proposed Glasnevin Station have been predicted to settle more than 30mm based on the Phase 1 settlement predictions and are therefore likely to require mitigation. A possible solution is to support the bridge deck on temporary bearings/jacks during the construction of Glasnevin Station and adjust the bearing levels in response to the actual settlement experienced and recorded by monitoring instrumentation. Other bridges which are away from the station box excavations are unlikely to require mitigation.

Intervention is likely to be required to adjust the track level (fettling of ballast) for the section of the Iarnród Éireann line passing adjacent to the proposed Tara Station during its construction. However, no intervention is anticipated for the Luas lines due to ground movements generated by MetroLink construction. An instrumentation and monitoring strategy with associated trigger levels will be developed and agreed with Iarnród Éireann and the Luas operator to verify that the actual settlements on site confirm the ongoing safe operation of these services.

For roads in close proximity to the station boxes and retained cuttings there is a possibility of surface cracking occurring during MetroLink construction, and localised surface repairs may therefore be required. Roads will need to be monitored and inspected regularly during the construction period, and maintenance and repair of the subbase and surface will be undertaken to maintain the stability and suitability of the road surface. This will be planned and agreed with the relevant highway authority.

No mitigations are anticipated for the aircraft stands and taxiway at Dublin Airport. Movement monitoring instrumentation and survey points will be installed across the areas that could potentially be impacted by construction generated ground movements to monitor any movement of the concrete pavement and any movement of the subgrade under the concrete pavement. Monitoring proposals will be developed by the D&B contractor and with DAA.

Cross Guns Quay canal lock and the associated structures (ST-5b) are not anticipated to undergo significant tilt, however due to their relatively close position to the proposed MetroLink Glasnevin Station, there is a risk that jamming of the gates may occur due to relative movements on the vertical guide rail which could impede gate operations. It is therefore anticipated that the gates will need to be monitored to inform any necessary periodic gate adjustment in response to any movement experienced.

No mitigation will be required for Ballymun Road petrol station (ST2) since it falls outside of the MetroLink settlement zone of influence, or for the Jim Larkin statue (ST-6) on O' Connell Street due to the limited size, structural form and support to the structure.

References

[Ref. 1] Farrell et al. (1995). The genesis if the brown boulder clay of Dublin, Quarterly Journal of Engineering Geology, 28, 143-145, The Geological Society.

[Ref. 2] Ground Investigation Report (GIR); ML1-JAI-GEO-ROUT_XX-RP-Y-00003.

[Ref. 3] Geotechnical Design Report (GDR); ML1-JAI-GEO-ROUT_XX-RP-Y-00004.

[Ref. 4] CIRIA 760 Guidance on embedded retaining wall design.

[Ref. 5] Peck (1969). Deep excavations and tunnelling in soft ground. In Proc. 7th Int. Conf. Soil Mech. Found. Engineering, 345–352, Stockholm.

[Ref. 6] O'Reilly, M.P. and New, B.M. (1982). Settlements above tunnels in the United Kingdom – their magnitude and prediction. Tunnelling '82. Ed Jones, M.J. pp 173-181. London, IMM.

[Ref. 7] O'Rourke et al., (1976). The ground movements related to braced excavation and their influence on adjacent structures. University of Illinois Report for US Department of Transportation, No. DOT-TST-76T22.

[Ref. 8] Burland, J.B., Broms, B.B., & de Mello, V.F.B. (1977). Behaviour of foundations and structures. Pages 495-546 of: Proc. 9th Int. Conf. Soil Mech. and Found. Eng., vol. 2.

[Ref. 9] Jennings and Kerrich (1962). The heaving of buildings and the associated economic consequences, with particular reference to the Orange Free State goldfields, Civil Engineering, Issue 11, January 1962.

[Ref. 10] UK National Coal Board (1975). Subsidence Engineers Handbook, National Coal Board Production Department, UK.

[Ref. 11] MacLeod and Littlejohn (1974). Discussion on Session 5, Proceedings Conference on Settlement of Structures, Pentech Press, London, UK, pp. 792-795.

[Ref. 12] Boscarding and Cordin (1989). Building response to excavation-induced settlement, Journal of Geotechnical Engineering, Vol. 115, No. 1, January 1989.

[Ref. 13] Rankin (1988). Ground movements resulting from urban tunnelling: predictions and effects. Pages 79-92 of: Engineering geology of underground movements. The Geological Society, London.

[Ref. 14] ICE Manual of Geotechnical Engineering; Vol. II (2012). ICE Publishing, London.

[Ref. 15] Network Rail Standard NR/L2/CIV/177: Monitoring track over or adjacent to Construction Works (2021)

[Ref. 16] Fuentes R. and Devriendt M. (2010). Ground movements around corners of excavations - An empirical calculation method. Journal of Geotechnical and Geoenvironmental Engineering. Volume 136, Issue 10, pp. 1414-1424.

Appendix A. Not Used

Appendix B. Building Classification List and Special Structures List

Appendix B.1 – Building List

Appendix B.2 – Special buildings

Appendix B.1: Buildings Identified from Building Survey

BUILDING CODE	BUILDING DESCRIPTION			BUILDING LOCATION			BUILDING INFORMATION			
	NAME	CONSIDERATION	CATEGORY	Chainage	Dmin (m)	Dmax (m)	Height (m)	Nº Floors	Length (m)	Depth (m)
B-1	Permanent TSB Head Office	Public	Prominent	18+620	31.37	96.28	20.0	4	64.91	-2.50
B-2	Loreto college	College	0	18+580	34.19	123.10	20.0	4	88.91	-3.00
B-3	OPW	Public	Public	18+500	34.87	146.21	25.0	6	111.34	-3.00
B-4	Department of Justice and Equality	Public	Public	18+520	33.64	94.33	20.0	3	60.69	-2.50
B-5	Australian Embassy	Public	Public	18+480	32.86	72.65	20.0	5	39.79	-2.50
B-6	Housing Finance Agency	Public	Public	18+460	32.33	65.26	20.0	5	32.93	0.00
B-7	Ivor Fitzpatrick and Co	Public	Public	18+420	31.68	63.26	20.0	5	31.58	-2.50
B-8	Boston College; St.Stephen's Green	Public	Public	18+400	32.53	54.74	13.0	4	22.21	-2.50
B-9	Forty one restaurant	Commerce	0	18+380	32.56	61.59	16.0	3	29.03	-2.50
B-10	Bank of Ireland	Commerce	0	18+380	32.61	58.67	15.0	3	26.06	-3.00
B-11	International Rugby Board	Public	Prominent	18+340	11.36	37.38	24.0	7	26.02	-3.10
B-12	The Spa	Public	Prominent	18+340	0.00	18.50	30.0	7	18.50	-6.60
B-13	Shelbourne Hotel	Hotel	0	18+320	21.02	61.46	30.0	7	40.44	-6.60
B-14	Department of Agriculture, Food & Marine	Public	Prominent	18+280	0.00	40.45	31.0	8	40.45	-4.00
B-15	Government Building	Public	Prominent	18+240	13.36	42.03	14.0	4	28.67	-3.00
B-16	Government Building	Public	Prominent	18+080	0.00	24.90	21.0	6	24.90	-3.00
B-17	Irish Parlament	Public	Prestigious	18+120	0.00	19.20	14.0	4	19.20	-6.20
B-18	National Museum of Ireland	Public	Public	18+180	7.04	76.27	20.0	2	69.23	-3.00
B-19	Natural History Museum	Public	Public	18+160	36.28	104.95	16.0	2	68.67	-3.00
B-20	National Library	Public	Prominent	18+080	21.61	88.55	14.0	4	66.94	-5.00
B-21	National galery of Ireland	Public	Prominent	17+980	5.83	43.21	25.0	5	37.38	-5.00
B-22	Trinity Point	0	Prominent	17+980	0.00	9.39	17.5	5	9.39	0.00
B-23	Trinity Point	Commerce	Prominent	18+020	24.44	53.22	21.0	6	28.78	0.00
B-24	Trinity Point	0	Prominent	18+020	0.00	9.39	17.5	5	9.39	0.00
B-25	Student Counselling Service	Public	Prominent	17+980	0.00	8.50	14.0	4	8.50	0.00
B-26	National galery of Ireland	0	Prominent	18+020	30.88	102.64	25.0	5	71.76	-5.00
B-27	National Gallery	Public	Prominent	18+020	8.15	43.48	25.0	5	35.33	-6.75
B-28	Residential	Residential	0	17+980	56.77	87.51	15.0	4	30.74	-2.50
B-29	Residential	Residential	0	17+940	29.52	41.16	14.0	4	11.64	-2.25
B-30	Insomnia	Commerce	Poor condition	17+940	0.00	2.68	19.0	4	2.68	-2.35
B-31	Trinity College	Residential	0	17+920	13.02	32.92	19.0	4	19.90	-2.50
B-32	Depto of Mechanical Manufacturing Engineering	Public	Poor condition	17+900	0.00	18.92	10.5	3	18.92	0.00
B-33	Dublin Dental University Hospital	Hospital	Hospital / Historical	17+900	0.00	3.31	19.0	4	3.31	-2.50
B-34	Dublin Dental University Hospital	Hospital	Hospital / Historical	17+880	0.00	3.31	19.0	4	3.31	-2.50
B-35	HTrinity College-Zoology	Public	Sensitive	17+840	0.00	15.58	10.5	3	15.58	0.00
B-36	Trinity College-Chemistry	Public	Public	17+800	14.85	70.90	10.5	3	56.05	0.00
B-37	Trinity College-Laser Unit	Public	Public	17+740	17.51	48.07	17.5	5	30.56	0.00
B-38	Trinity College-Phisics	Public	prestigious	17+760	0.00	17.98	14.0	4	17.98	0.00
B-39	Trinity College-Botany	Public	Public	17+720	0.00	18.19	7.0	2	18.19	0.00
B-40	Luce Hall	Public	Public	17+700	0.00	1.30	17.5	5	1.30	0.00
B-41	Engineering laboratory	Public	Public	17+680	3.37	64.49	14.0	4	61.12	0.00
B-42	Trinity Business School	Commerce & Residential	0	17+660	14.52	20.03	10.5	3	5.51	0.00
B-43	Unknown	0	0	17+640	66.62	106.83	17.6	2	40.21	-1.80

BUILDING CODE	BUILDING DESCRIPTION			BUILDING LOCATION			BUILDING INFORMATION			
	NAME	CONSIDERATION	CATEGORY	Chainage	Dmin (m)	Dmax (m)	Height (m)	Nº Floors	Length (m)	Depth (m)
B-44	GoHop-Ireland's internet travel company	Commerce & Residential	0	17+620	14.80	29.53	13.0	3	14.73	-2.80
B-45	O'Neils whiskey bonders	Commerce & Residential	0	17+620	0.00	4.13	12.0	3	4.13	-2.00
B-46	O'Neils TownHouse	Commerce & Residential	0	17+600	1.02	13.02	14.0	3	12.00	-2.00
B-47	World Travel	Commerce & Residential	0	17+600	0.00	6.30	11.6	3	6.30	-2.20
B-48	The school Tour company	Commerce & Residential	0	17+580	0.00	0.40	11.6	3	0.40	-2.20
B-49	Mc Carty Centre	Offices	0	17+560	6.43	36.59	18.5	5	30.16	0.00
B-50	Solvar Fields Ltd.	Offices	Prominent	17+540	0.00	6.34	26.0	4	6.34	-3.50
B-51	Dublin Fire Brigade & Commercial	Public & Commercial	Public	17+500	0.00	13.10	30.0	6	13.10	-2.50
B-52	National Concert Hall	0	Prestigious	18+840	5.55	122.84	10.5	3	117.29	0.00
B-53	Public	0	Prominent Building	18+920	0.00	3.00	14.0	4	3.00	0.00
B-54	The Irish Times	Public	Public	17+400	36.66	74.54	36.0	7	37.88	-3.00
B-55	Residential	0	0	18+980	8.44	22.92	19.0	4	14.48	-2.00
B-56	Tara House	Old Building	0	17+320	0.00	11.89	10.5	3	11.89	0.00
B-57	Starbucks caffee	Commerce & Residential	0	17+260	0.00	6.55	16.0	5	6.55	0.00
B-58	Unknown	0	0	17+220	42.88	68.08	14.0	2	25.20	0.00
B-59	Eden House	Public	Public	17+120	4.06	36.60	14.0	4	32.54	-3.70
B-60	Abbey Theatre	Public	Public	17+100	29.98	80.85	14.0	4	50.87	0.00
B-61	Billiard World Class travel sport	Commerce & Residential	0	17+080	20.95	43.39	14.0	4	22.44	-2.50
B-62	Church Methodist	Public	Public	17+040	39.80	70.57	14.0	4	30.77	0.00
B-63	Veritas House	Commercial	0	17+000	20.42	48.28	14.0	4	27.86	0.00
B-64	College	Public	Public	16+980	39.00	81.38	17.5	5	42.38	0.00
B-65	Clearys shopcenter	Commercial	0	16+920	7.22	98.27	14.0	4	91.05	0.00
B-66	Ann Summers	Commercial	0	16+860	37.47	66.46	17.5	5	28.99	0.00
B-67	General Post Office	Public	Cultural & Historical	16+860	0.00	5.31	20.0	5	5.31	-2.81
B-68	Mc Dowels	Commercial	0	16+800	54.65	67.99	21.0	6	13.34	-3.00
B-69	Unknown	0	0	16+720	123.22	170.75	14.0	4	47.53	0.00
B-70	Carlton Theatre	Public	Public	16+680	0.00	15.36	20.0	3	15.36	0.00
B-71	Savoy Cinema	Public	Public	16+660	61.51	116.83	17.5	5	55.32	0.00
B-72	The Gresham Hotel;Station O'Conell Street	Hotel	0	16+600	61.34	117.23	17.5	5	55.89	-3.00
B-74	Unknown	0	0	16+600	0.65	15.92	14.0	4	15.27	0.00
B-75	Unknown	0	0	16+600	0.00	16.75	17.2	5	16.75	-3.30
B-76	Unknown	0	0	16+580	0.00	16.75	20.0	4	16.75	-3.90
B-77	AIB Bank	Commerce & Residential	0	16+540	0.00	17.06	18.0	4	17.06	-3.35
B-78	Parnell Monument	Monument	Cultural & Historical	16+500	29.35	43.51	19.0	4	14.16	0.00
B-79	Rotunda Hospital, Parnell Square East	Hospital	Hospital / Historical	16+480	7.33	140.49	14.0	4	133.16	-3.00
B-80	Rotunda IVF clinic	Hospital	Hospital / Historical	16+400	3.70	34.39	7.0	2	30.69	0.00
B-81	The Ambassador teatre	Public	Historical	16+460	0.00	18.06	14.0	4	18.06	-3.00
B-82	Gate theatre	Public	Hospital / Historical	16+440	0.00	15.48	10.5	3	15.48	-3.00
B-83	Netprint café	Commercial & Residential	0	16+460	49.21	71.43	12.0	4	22.22	-1.58
B-84	Cassidys Hotel	Hotel	0	16+440	40.07	87.59	14.0	4	47.52	-1.66
B-85	Cassidys Hotel	Hotel	0	16+440	40.07	87.59	14.0	4	47.52	-1.66
B-86	Residential	Residential	0	16+420	34.55	67.40	14.0	4	32.85	0.00
B-87	Gaelscoil Cholaiste Mhuire & The Charles Stewart Dublin - Guest Accommodation	Residential	0	16+380	19.35	80.05	16.0	4	60.70	-3.30
B-88	Youthreach Transition Centre	Residential	0	16+320	10.91	39.65	14.0	4	28.74	0.00
B-89	Residential	Residential	prominent	16+280	4.32	66.96	14.0	4	62.64	0.00

BUILDING CODE	BUILDING DESCRIPTION			BUILDING LOCATION			BUILDING INFORMATION			
	NAME	CONSIDERATION	CATEGORY	Chainage	Dmin (m)	Dmax (m)	Height (m)	Nº Floors	Length (m)	Depth (m)
B-90	Abbey Presbiterian church	Public	cultural&Historical	16+240	18.22	37.57	8.0	2	19.35	-2.60
B-91	Residential Houses & Hotels	Hotel	Poor condition	16+200	0.61	23.39	14.5	5	22.78	-3.40
B-92	Unknown	Commercial & Residential	prominent	16+140	12.62	41.91	12.5	4	29.29	-3.00
B-93	Capital Loan	Commercial & Residential	0	16+100	3.81	26.55	12.0	4	22.74	-2.60
B-94	Finn travel agency	Commercial & Residential	0	16+080	12.94	29.17	12.5	4	16.23	-3.00
B-95	Sackvile court Apartments	Commercial	0	16+020	0.00	18.42	15.0	5	18.42	0.00
B-96	Embassy	Public	Public	15+980	13.36	34.49	14.0	4	21.13	-1.55
B-97	Unknown	0	0	15+940	0.00	9.56	14.0	4	9.56	0.00
B-98	Unknown	0	0	15+920	0.00	17.03	9.0	4	17.03	-1.45
B-99	Unknown	Commercial & Residential	0	15+860	3.96	23.71	10.0	3	19.75	-2.50
B-100	Unknown	Commercial & Residential	0	15+820	0.00	5.27	10.5	3	5.27	0.00
B-101	Joseph's church	Public	High Value	15+720	0.00	31.09	20.0	5	31.09	-2.20
B-102	Mater Misericordia Hospital	Hospital	Hospital / Historical	15+560	15.48	242.43	10.5	3	226.95	-3.00
B-103	Deli Fruit Selections	Commerce	0	15+540	0.00	12.74	7.0	2	12.74	0.00
B-104	Unknown	0	0	15+540	0.00	12.74	7.0	2	12.74	0.00
B-105	Group of Residential Houses	Residential	0	15+460	0.00	12.63	6.5	2	12.63	-1.00
B-106	Residential	Residential	0	15+440	0.00	7.09	8.5	2	7.09	-1.00
B-107	Residential	Residential	0	15+420	2.00	17.42	11.5	3	15.42	-0.80
B-108	Jyoti Yoga Shala	Commercial	0	15+400	0.00	8.17	11.0	3	8.17	-2.50
B-109	The butchers	Commercial	0	15+360	1.23	20.40	7.0	2	19.17	-0.80
B-110	Library view villas	Public	Public	15+340	0.00	7.86	7.2	2	7.86	-1.20
B-111	Phibsboro Library	Public	Public	15+340	11.28	36.22	6.0	1	24.94	-1.20
B-112	Unknown	0	0	15+320	8.64	48.83	14.0	4	40.19	0.00
B-113	MacDonalds	Commercial	0	15+220	0.00	32.76	10.0	2	32.76	0.00
B-114	Comercios;antiguo	Commercial	0	15+200	0.00	16.17	3.0	1	16.17	0.00
B-115	Residential	Residential	0	15+160	1.37	11.15	10.5	3	9.78	0.00
B-116	Residential	Residential	0	15+080	0.00	20.05	7.0	2	20.05	0.00
B-117	Commercial	Commercial	0	14+980	5.68	20.12	10.5	3	14.44	0.00
B-118	Residential	Residential	0	14+980	0.00	9.80	14.0	4	9.80	0.00
B-119	Hotel	Hotel	0	14+700	8.19	16.55	7.0	2	8.36	0.00
B-120	Residential	Residential	0	14+580	1.56	15.42	7.0	2	13.86	0.00
B-121	Residential Houses	Residential	0	14+760	0.00	6.91	5.4	2	6.91	-1.00
B-122	Hotel	Hotel	0	14+520	0.00	6.37	9.0	3	6.37	-1.00
B-123	Residential houses	Residential	0	14+400	2.63	23.66	7.0	2	21.03	0.00
B-124	Victories Church;Station Collins Avenue	Public	cultural&Historical	12+200	32.81	92.58	7.0	2	59.77	0.00
B-125	Ballymun library	Public	0	11+920	0.00	25.65	4.7	1	25.65	0.00
B-126	CEBT-Adult Education Service	Public	0	11+780	0.00	28.28	4.7	1	28.28	0.00
B-127	Ballymun Leisure Center	Commercial	0	11+400	0.00	78.33	17.5	5	78.33	-3.00
B-128	Gateway Students Village	Public	0	11+460	56.38	91.82	14.0	4	35.44	0.00
B-129	Ballymun Civic Centre	Public	0	11+360	88.82	163.40	14.0	4	74.58	0.00
B-130	Unknown	0	0	10+860	52.27	88.50	21.0	6	36.23	0.00
B-131	Terminal 2, Terminal Complex, Dublin Airport, Swords, Co. Dublin	Dublin Airport Terminal 2	Public	7+300	0.00	24.49	17.5	5	24.49	-3.00
B-132	Airport Hangars	Public	Public	6+820	0.25	291.65	7.0	2	291.40	0.00
B-133	Fuel Station	Commercial	0	5+120	32.70	66.57	3.5	1	33.87	0.00
B-134	Smiths Toys Superstores. Commercial Center	Commercial	0	4+840	0.00	46.12	14.0	4	46.12	0.00

BUILDING CODE	BUILDING DESCRIPTION			BUILDING LOCATION			BUILDING INFORMATION			
	NAME	CONSIDERATION	CATEGORY	Chainage	Dmin (m)	Dmax (m)	Height (m)	Nº Floors	Length (m)	Depth (m)
B-135	Residential Houses	Residential	0	4+840	72.80	83.78	7.0	2	10.98	0.00
B-136	Fujitsu Ireland Ltd	Commercial	0	4+000	8.60	88.06	10.5	3	79.46	-1.50
B-137	Balheary Bridge	Bridge	0	1+620	11.40	31.58	0.0	0	20.18	0.00
B-138	Lissenhall Medieval Bridge	Bridge	0	1+520	35.20	48.42	0.0	0	13.22	0.00
B-139	Unknown	0	0	14+560	0.00	8.05	7.0	2	8.05	0.00
B-140	Unknown	0	0	14+560	0.00	8.73	7.0	2	8.73	-1.00
B-141	Residential	Residential	0	14+480	9.09	20.20	7.0	2	11.11	0.00
B-142	Residential	Residential	0	13+940	4.28	15.43	5.5	2	11.15	0.00
B-143	Unknown	0	0	13+840	72.61	157.34	12.5	3	84.73	-3.00
B-144	Unknown	0	0	13+460	13.30	23.70	7.0	2	10.40	0.00
B-145	Residential	Residential	0	12+900	16.67	29.60	8.8	2	12.93	0.00
B-146	Unknown	0	0	16+700	61.64	79.54	17.5	5	17.90	0.00
B-147	Davitt House	Hotel	Prominent Building	19+020	0.00	26.02	12.0	4	26.02	-2.50
B-148	Residential	0	0	19+100	21.21	58.96	11.8	3	37.75	0.00
B-149	Residential	0	0	19+160	7.84	25.22	15.0	4	17.38	-2.50
B-150	Residential	0	0	19+300	16.10	28.19	10.5	3	12.09	0.00
B-151	Residential	0	0	19+440	0.00	10.61	7.0	2	10.61	0.00
B-152	Residential	0	0	19+480	21.91	31.90	7.0	2	9.99	0.00
B-153	Unknown	0	0	19+600	67.40	73.97	7.0	2	6.57	0.00
B-154	Residential	0	0	19+820	38.95	51.20	7.0	2	5.96	0.00
B-155	Residential	Residential	0	20+055	22.24	39.32	10.5	3	17.08	0.00
B-156	Unknown	0	0	20+148	9.96	15.46	7.0	2	5.50	0.00
B-157	Residential	Residential	0	14+800	0.00	20.41	10.5	3	20.41	0.00
B-158	Bank of Ireland	Commercial	0	14+220	0.00	19.68	7.0	2	19.68	0.00
B-159	Residential	Residential	0	14+000	0.62	10.57	7.0	2	9.95	0.00
B-160	Residential	Residential	0	14+000	0.00	3.29	6.0	2	3.29	0.00
B-161	Residential	Residential	0	13+160	20.98	30.62	8.8	2	9.64	-1.00
B-162	Residential	Residential	0	13+180	20.81	33.01	7.0	2	12.20	0.00
B-163	Residential	Residential	0	13+140	10.52	19.43	7.0	2	8.91	0.00
B-164	Residential	Residential	0	13+120	10.51	22.22	8.7	2	11.71	0.00
B-165	Residential	Residential	0	10+760	12.27	68.63	12.5	4	56.36	-3.60
B-166	Terminal 2 Gates 407 to 426, Terminal Complex, Dublin Airport, Swords, Co. Dublin	Dublin Airport Term. 2 Gates 407 - 426	Public	7+580	0.00	78.46	14.0	4	78.46	-3.00
B-167	Dublin Airport Parking	Public	Public	6+980	36.60	132.63	17.5	5	96.03	-3.00
B-168	Nevinstown Lodge, Nevinstown West, Swords, Co. Dublin	Residential	0	5+120	0.00	5.00	3.5	1	5.00	0.00
B-172	Emerald Casino	0	0	17+080	10.37	36.16	14.0	4	25.79	-2.40
B-173	Clifton Court Bar	Commerce & Residential	0	17+080	1.87	31.39	17.5	5	29.52	0.00
B-174	Lanigans Restaurant	Commerce & Residential	0	17+080	0.43	20.14	10.5	3	19.71	0.00
B-175	Samaritans Dublin	Church	0	17+100	0.00	4.08	14.0	4	4.08	-2.60
B-176	Photocare	Commerce & Residential	0	17+080	0.85	30.70	14.0	4	29.85	-2.50
B-177	Eurogiant	Commerce & Residential	0	17+060	0.00	26.47	14.0	4	26.47	-3.80
B-178	Amplifon	Commerce & Residential	0	17+060	0.00	12.77	14.0	4	12.77	-4.10
B-179	Spar	Commerce & Residential	0	17+040	0.00	12.74	14.0	3	12.74	-3.70
B-187	Veritas.ie	0	0	17+000	11.18	38.96	14.0	4	27.78	0.00
B-188	Reynolds	0	0	17+000	6.22	25.90	14.8	4	19.68	-3.38
B-189	ladbrokes	0	0	17+000	1.00	22.95	14.0	4	21.95	0.00

BUILDING CODE	BUILDING DESCRIPTION			BUILDING LOCATION			BUILDING INFORMATION			
	NAME	CONSIDERATION	CATEGORY	Chainage	Dmin (m)	Dmax (m)	Height (m)	Nº Floors	Length (m)	Depth (m)
B-190	Coojum Restaurant	Commerce & Residential	poor condition	16+980	0.00	9.65	17.5	5	9.65	0.00
B-191	Permanent tsb	0	0	16+980	0.00	1.00	21.0	6	1.00	0.00
B-192	paddywagon	0	0	16+960	0.00	2.80	18.0	5	2.80	-3.00
B-193	Londis	0	Poor condition	16+960	0.00	7.64	18.0	5	7.64	-2.70
B-194	Indulge	0	0	16+960	0.00	4.26	21.0	6	4.26	0.00
B-195	Tourist office	0	0	16+960	0.00	26.57	21.0	6	26.57	0.00
B-198	Unknown	0	0	16+780	0.00	12.52	15.0	4	12.52	-3.80
B-199	Unknown	0	0	16+780	0.00	11.89	15.0	5	11.89	-3.90
B-200	CoCoBo. Chocolate	Commerce & Residential	0	16+760	0.00	11.48	17.5	5	11.48	-3.60
B-201	Unknown	0	0	15+280	0.00	27.12	14.0	4	27.12	0.00
B-202	Unknown	0	0	14+960	31.01	74.73	24.5	7	43.72	0.00
B-203	Residential	0	0	20+048	18.83	30.04	7.0	2	11.23	0.00
B-204	Residential	0	0	20+053	18.83	30.04	7.0	2	11.19	0.00
B-205	Residential	0	0	20+058	18.83	30.04	8.5	2	10.97	0.00
B-206	Residential	0	0	20+016	12.41	29.61	9.5	3	17.02	0.00
B-207	Residential	0	0	19+997	7.00	17.52	7.0	2	10.48	0.00
B-208	Residential	0	0	19+999	11.41	21.85	7.0	2	10.40	0.00
B-209	Commerce & Residential	0	0	19+949	14.33	28.37	11.0	3	14.49	0.00
B-210	Commerce & Residential	0	0	19+908	30.08	41.84	8.3	2	11.90	0.00
B-211	Commerce & Residential	0	0	19+915	30.11	37.84	8.3	2	7.78	0.00
B-212	Residential	0	0	19+831	50.15	62.42	11.1	3	3.36	-2.30
B-213	Residential	0	0	19+820	46.08	57.08	11.1	3	4.51	-2.30
B-214	Commerce & Residential	0	0	19+820	68.48	84.48	9.4	2	18.02	0.00
B-215	Commerce & Residential	0	0	19+820	72.64	89.02	9.4	2	17.63	0.00
B-216	Ranelagh Station	Public	0	19+800	58.03	65.48	9.6	2	8.71	0.00
B-217	Kids Inc - Creche & Montessori, Ranelagh	Public	0	19+700	0.00	21.51	10.0	3	21.51	0.00
B-218	Residential	0	0	19+660	47.62	59.80	8.2	2	12.18	0.00
B-219	Residential	0	0	19+660	47.41	59.67	8.1	2	12.26	0.00
B-220	Residential	0	0	19+620	9.06	19.24	11.4	3	10.18	0.00
B-221	Residential	0	0	19+620	12.29	23.24	11.4	3	10.95	0.00
B-222	Residential	0	0	19+540	2.26	9.32	11.4	3	7.06	0.00
B-223	Residential	0	0	19+540	6.38	13.96	11.4	3	7.58	0.00
B-224	Residential	0	0	19+520	3.83	10.71	7.0	2	6.88	0.00
B-225	Residential	0	0	19+520	0.00	6.72	7.0	2	6.72	0.00
B-226	Unknown	0	0	19+400	0.00	5.64	7.0	2	5.64	0.00
B-227	Unknown	0	0	19+400	0.00	8.02	7.0	2	8.02	0.00
B-228	Residential	0	Prominent Building	19+300	11.99	60.31	24.5	7	48.32	0.00
B-230	Hertz, Swords Business Park, Swords, Co. Dublin	Commercial	0	2+840	16.60	213.02	12.0	2	196.42	0.00
B-231	Our Lady Queen of Corballis Heaven, Corballis Road North, Dublin Airport, Swords Co. Dublin	Church	Church	7+040	58.33	105.53	7.0	2	47.20	0.00
B-232	The Sentinel Building, Gateway View, Dublin 11 - Apartments 1-8 & Retail Unit	Commercial & Residential	0	11+480	14.05	25.26	31.5	9	11.21	0.00
B-233	Apartments 40-42, Gateway View Dublin 11	Residential	0	11+500	2.38	13.47	12.2	4	11.09	0.00
B-234	Unknown	0	0	14+820	145.52	153.40	7.1	2	7.88	0.00
B-235	54 Goldsmith St, Phibsborough, Dublin 7	Residential	0	15+460	8.27	22.95	3.5	1	14.68	0.00
B-236	15 Berkeley Road, Phibsborough, Dublin 7	Commercial & Residential	0	15+620	29.30	46.54	7.0	2	17.24	0.00
B-237	Unknown	0	0	15+680	29.60	42.63	7.0	2	13.03	0.00

BUILDING CODE	BUILDING DESCRIPTION			BUILDING LOCATION			BUILDING INFORMATION			
	NAME	CONSIDERATION	CATEGORY	Chainage	Dmin (m)	Dmax (m)	Height (m)	Nº Floors	Length (m)	Depth (m)
B-238	Arthur Cox Building	0	0	18+980	0.00	17.81	40.0	7	17.81	-8.10
B-239	Residential	Residential	0	13+120	10.51	15.50	8.7	2	4.99	0.00
B-240	Presbytery, Corballis Road North, Dublin Airport, Swords Co. Dublin	Presbytery	Church	7+060	42.92	61.12	7.0	2	18.20	0.00
B-241	Hotel Winns	Hotel	0	17+020	0.00	4.26	21.0	6	4.26	-3.00
B-242	Residential	0	0	19+760	51.95	61.79	10.5	3	10.08	0.00
B-243	Unknown	0	0	14+840	121.02	133.44	7.9	3	12.42	0.00
B-244	Residential	Residential	0	14+100	0.00	11.03	7.0	2	11.03	0.00
ST-1	Airport Road	Road	Road	8+320	0.00	115.66	0.0	0	115.66	0.00
ST-2	Ballymum's Road Gas Station	Petrol Station	Petrol Station	12+860	26.55	49.28	0.0	0	62.96	0.00
ST-3	Mobhi's Road Bridge	Bridge	Single Span	13+900	17.66	37.03	0.0	0	21.75	0.00
ST-4	Railway	Railwway	Railway	14+880	0.00	116.51	0.0	0	116.51	0.00
ST-5	Near Cross Guns Quay (nearly B-202) / Floodgates	Watergate	Watergate	14+940	0.00	41.06	0.0	0	41.06	0.00
ST-6	O'Conell Street cross	Main Street	Road	16+900	0.00	57.64	0.0	0	57.64	0.00
ST-7	Bridge between O´Conell Street and Butt Bridge	Bridge	Multiple Span	17+120	9.11	67.72	0.0	0	48.05	0.00
ST-8	Bridge over Pootberg Street corner with Lucke Street	Bridge	Single Span	17+380	22.81	42.47	0.0	0	36.33	0.00
ST-9	Bridge over Townsend Street	Bridge	Single Span	17+500	23.05	31.94	0.0	0	21.13	0.00
ST-10	Bridge Over Shaw Street	Bridge	Single Span	17+580	25.39	41.19	0.0	0	38.89	0.00
ST-11	Bridge over Dartmouth Road	Bridge	Single Span	19+420	7.68	21.74	0.0	0	17.42	0.00
ST-12	Bridge over Northbrook Road	Bridge	Single Span	19+520	9.42	21.13	0.0	0	15.15	0.00
ST-13	Bridge over Ranelagn Road	Bridge	Single Span	19+780	24.89	39.94	0.0	0	53.47	0.00
ST-14	Bridge over Cullenswood Road	Bridge	Single Span	19+943	2.69	14.67	0.0	0	15.83	0.00
ST-15	Embankment carrying LUAS, masonry faced circa 4-5m in height, interspersed with ST-11 to ST-14	Embankment	Embankment	19+350 – 19+750	0	35	5	0	400	0

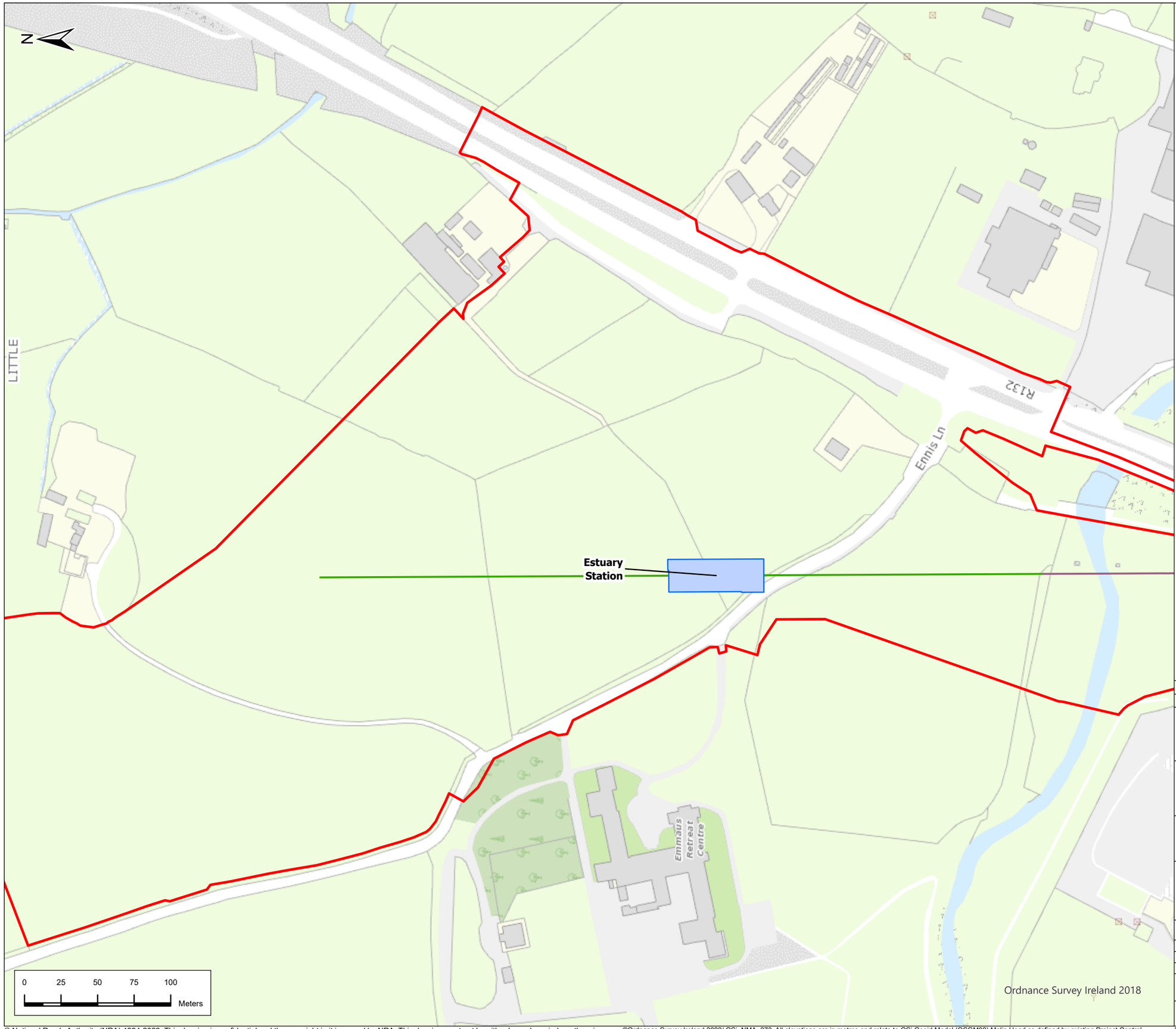
Appendix B.2: List of Special Structures with reasoning

Building Ref	Name	Reason for inclusion	Chainage
B-1	Permanent TSB Head Office	Prominent	18+620
B-3	OPW	Public	18+500
B-4	Deparment of Justice and Equality	Public	18+520
B-5	Australian embassy	Public	18+480
B-6	Housing Finance Agency	Public	18+460
B-7	Ivor Fitzpatrick and Co	Public	18+420
B-8	Boston College;St.Stephen's Green	Public	18+400
B-11	International Rugby Board	Prominent	18+340
B-12	The Spa	Prominent	18+340
B-14	Department of Agriculture, Food & Marine	Prominent	18+280
B-15	Government Building	Prominent	18+240
B-16	Government Building	Prominent	18+080
B-17	Irish Parlament	Prestigious	18+120
B-18	National Museum of Ireland	Public	18+180
B-19	Natural History Museum	Public	18+160
B-20	National Library	Prominent	18+080
B-21	National galery of Ireland	Prominent	17+980
B-22	Trinity Point	Prominent	17+980
B-23	Trinity Point	Prominent	18+020
B-24	Trinity Point	Prominent	18+020
B-25	Student Counselling Service	Prominent	17+980
B-26	National galery of Ireland	Prominent	18+020
B-27	National Gallery	Prominent	18+020
B-30	Insomnia	Poor condition	17+940
B-32	Depto of Mechanical Manufacturing Engineering	Poor condition	17+900
B-33	Dublin Dental University Hospital	Hospital / Historical	17+900
B-34	Dublin Dental University Hospital	Hospital / Historical	17+880
B-35	HTrinity College-Zoology	Sensitive	17+840
B-36	Trinity College-Chemistry	Public	17+800
B-37	Trinity College-Laser Unit	Public	17+740
B-38	Trinity College-Phisics	prestigious	17+760
B-39	Trinity College-Botany	Public	17+720
B-40	Luce Hall	Public	17+700
B-41	Engineering laboratory	Public	17+680
B-50	Solvar Fields Ltd.	Prominent	17+540
B-51	Dublin Fire Brigade & Commercial	Public	17+500
B-52	National Concert Hall	Prestigious	18+840
B-53	Public	Prominent Building	18+920
B-54	The Irish Times	Public	17+400
B-59	Eden House	Public	17+120
B-60	Abbey Theatre	Public	17+100
B-62	Church Methodist	Public	17+040
B-64	College	Public	16+980
B-67	General Post Office	Cultural & Historical	16+860

Building Ref	Name	Reason for inclusion	Chainage
B-70	Carlton Theatre	Public	16+680
B-71	Savoy Cinema	Public	16+660
B-78	Parnell Monument	Cultural & Historical	16+500
B-79	Rotunda Hospital, Parnell Square East	Hospital / Historical	16+480
B-80	Rotunda IVF clinic	Hospital / Historical	16+400
B-81	The Ambassador teatre	Historical	16+460
B-82	Gate theatre	Hospital / Historical	16+440
B-89	Residential	prominent	16+280
B-90	Abbey Presbiterian church	cultural&Historical	16+240
B-91	Residential Houses & Hotels	Poor condition	16+200
B-92	Unknown	prominent	16+140
B-96	Embassy	Public	15+980
B-101	Joseph's church	High Value	15+720
B-102	Mater Misericordia Hospital	Hospital / Historical	15+560
B-110	Library view villas	Public	15+340
B-111	Phibsboro Library	Public	15+340
B-124	Victories Church;Station Collins Avenue	cultural&Historical	12+200
B-131	Terminal 2, Terminal Complex, Dublin Airport, Swords, Co. Dublin	Public	7+300
B-132	Airport Hangars	Public	6+820
B-147	Davitt House	Prominent Building	19+020
B-166	Terminal 2 Gates 407 to 426, Terminal Complex, Dublin Airport, Swords, Co. Dublin	Public	7+580
B-167	Dublin Airport Parking	Public	6+980
B-190	Coojum Restaurant	poor condition	16+980
B-193	Londis	Poor condition	16+960
B-228	Residential	Prominent Building	19+300
B-231	Our Lady Queen of Corballis Heaven, Corballis Road North, Dublin Airport, Swords Co. Dublin	Church	7+040
B-240	Presbytery, Corballis Road North, Dublin Airport, Swords Co. Dublin	Church	7+060
ST-1	Airport Road	Road	8+320
ST-2	Ballymum's Road Gas Station	Pass to Phase 2b	12+860
ST-3	Mobhi's Road Bridge	Pass to Phase 2b	13+900
ST-4	Railway	Pass to Phase 2b	14+880
ST-5	Near Cross Guns Quay (nearly B-202) / Floodgates	Pass to Phase 2b	14+940
ST-6	O'Conell Street cross	Pass to Phase 2b	16+900
ST-7	Bridge between O´Conell Street and Butt Bridge	Pass to Phase 2b	17+120
ST-8	Bridge over Pootberg Street corner with Lucke Street	Pass to Phase 2b	17+380
ST-9	Bridge over Townsend Street	Pass to Phase 2b	17+500
ST-10	Bridge Over Shaw Street	Pass to Phase 2b	17+580
ST-11	Bridge over Dartmouth Road	Pass to Phase 2b	19+420
ST-12	Bridge over Northbrook Road	Pass to Phase 2b	19+520
ST-13	Bridge over Ranelagn Road	Pass to Phase 2b	19+780
ST-14	Bridge over Cullenswood Road	Pass to Phase 2b	19+943
ST-15	Embankment carrying LUAS, masonry faced circa 4-5m in height, interspersed with ST-11 to ST-14	Pass to Phase 2b	19+350 – 19+750

Appendix C. Phase 1 Settlement Contour Drawings

Appendix C: Greenfield Settlement Contours ML1-JAI-EIA-ROUT_XX-DR-Y-21120



Legend

Alignment
- Surface
- Viaduct
- Station Locations
- Project Boundary

Geographic Split
- AZ1 Northern Section

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 1 of 30

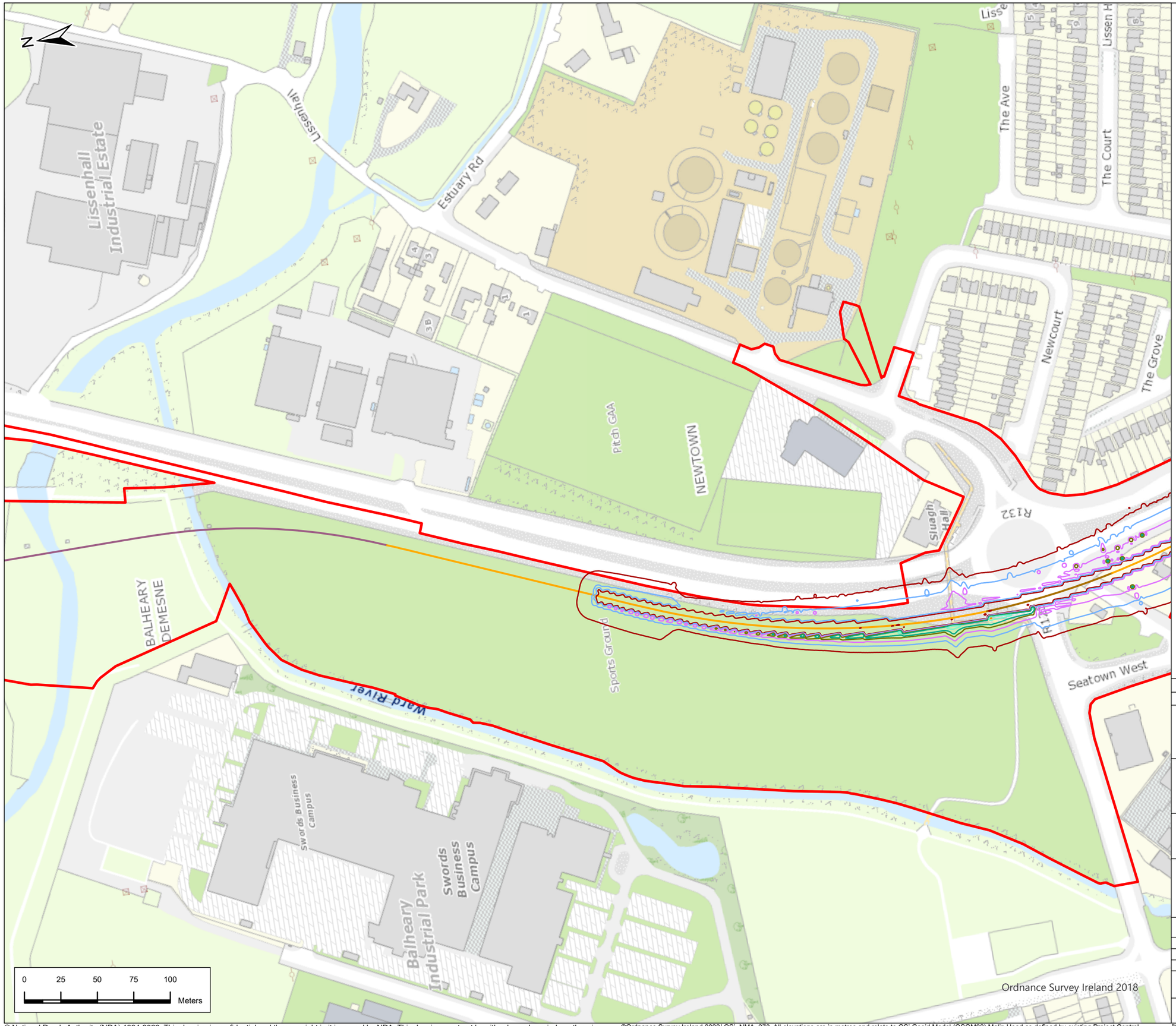
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21121	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\IR\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

- Cut & Cover
- Retained Cut
- Viaduct
- Station Locations
- Project Boundary

Geographic Split

- AZ1 Northern Section

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 2 of 30

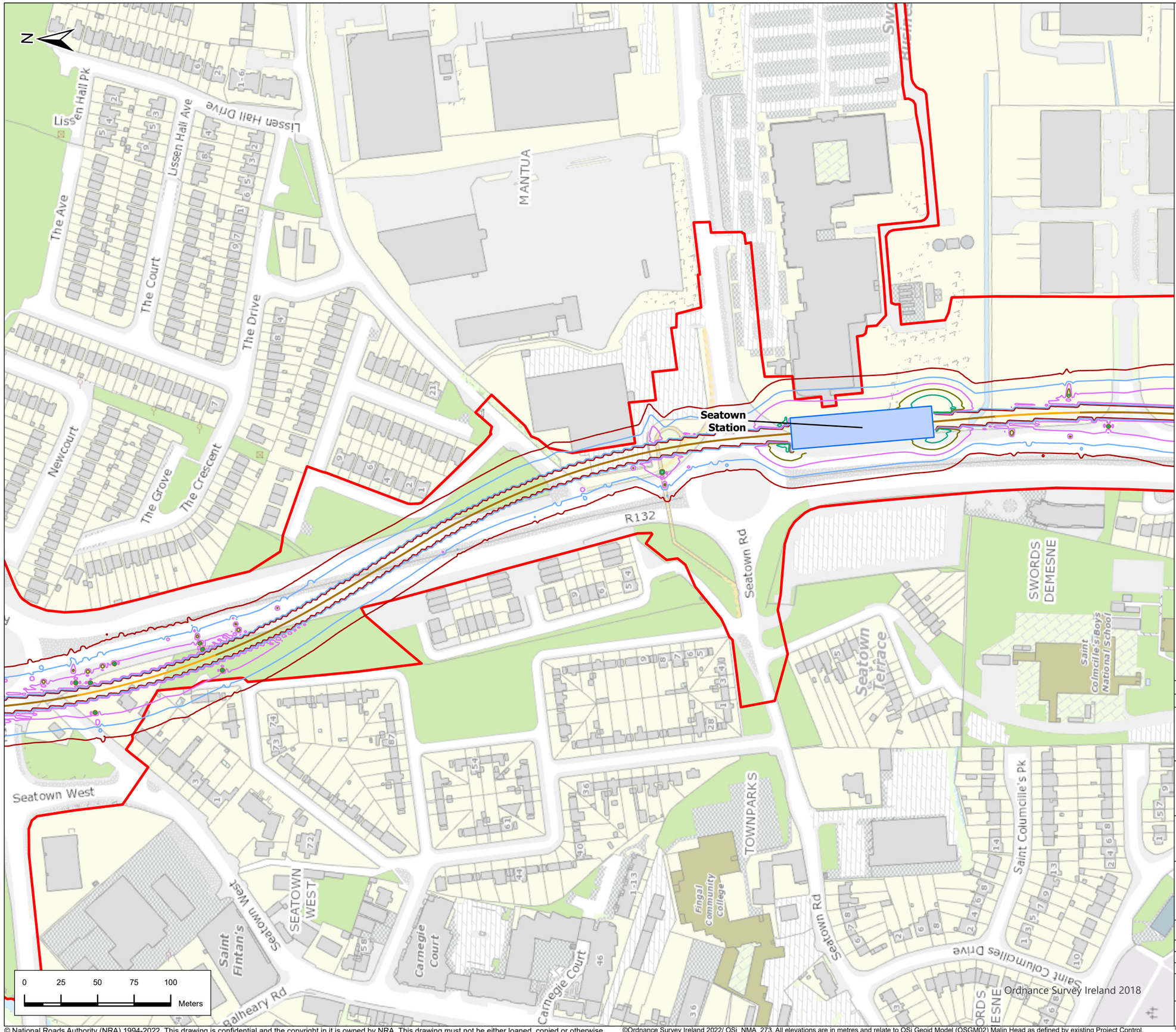
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21122	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\IJI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment
- Cut & Cover
- Retained Cut
- Station Locations
- Project Boundary

Geographic Split
- AZ1 Northern Section

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 3 of 30

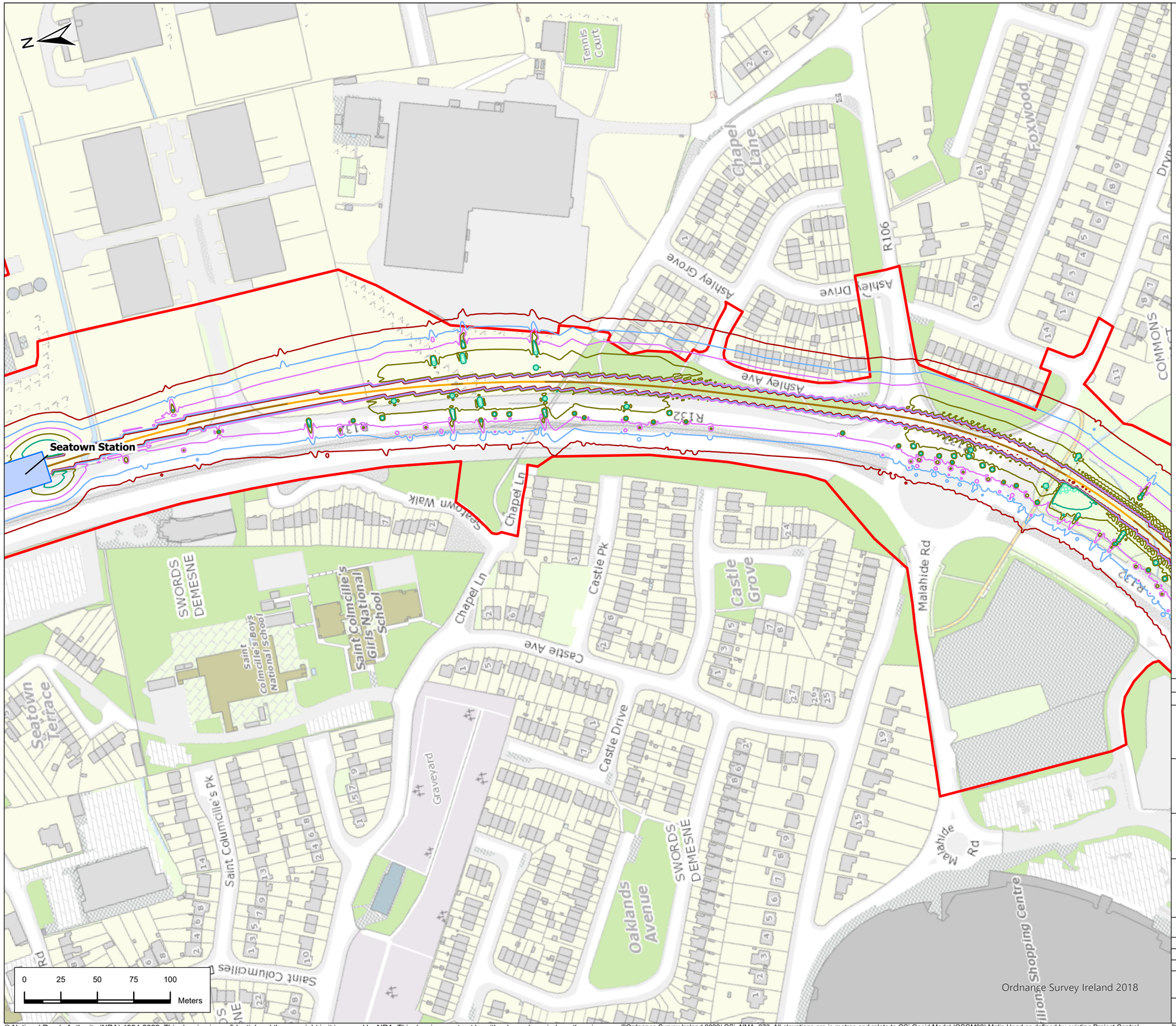
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21123	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\IT\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx

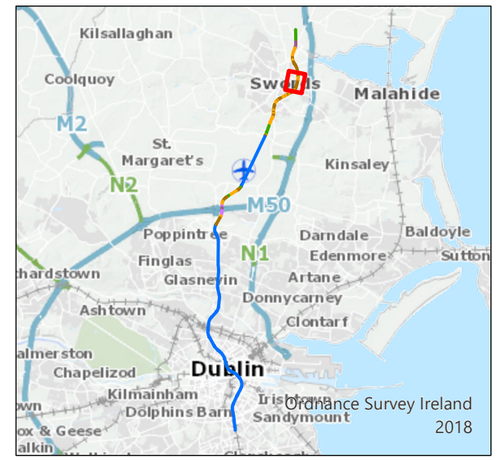


Legend

Alignment
- Cut & Cover
- Retained Cut
- Station Locations
- Project Boundary

Geographic Split
- AZ1 Northern Section

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

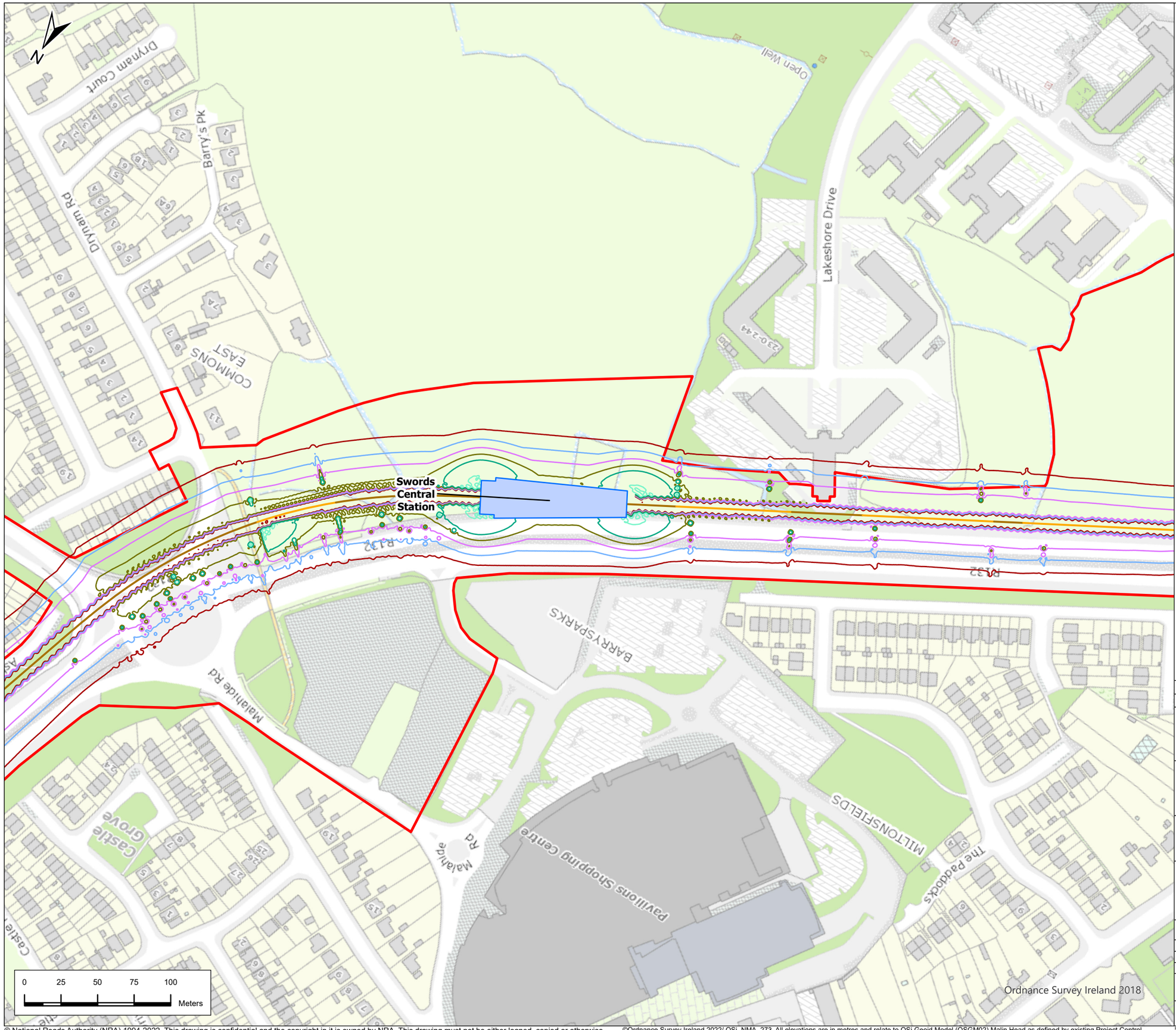
Drawing Title: Figure 20.16 Settlement Contours
Sheet 4 of 30

Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21124	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

Path: \\europe.jacobs.com\Dublin\Data\IT\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

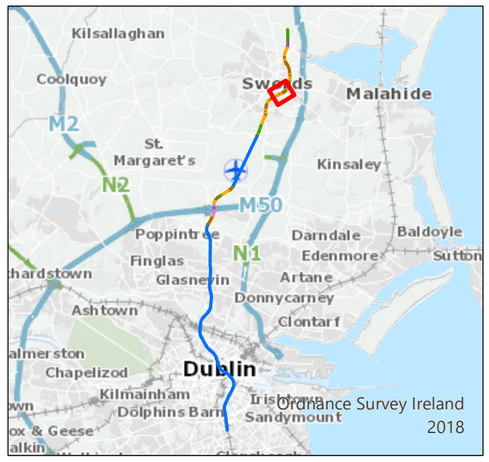
- Cut & Cover
- Retained Cut
- Station Locations
- Project Boundary

Geographic Split

- AZ1 Northern Section

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

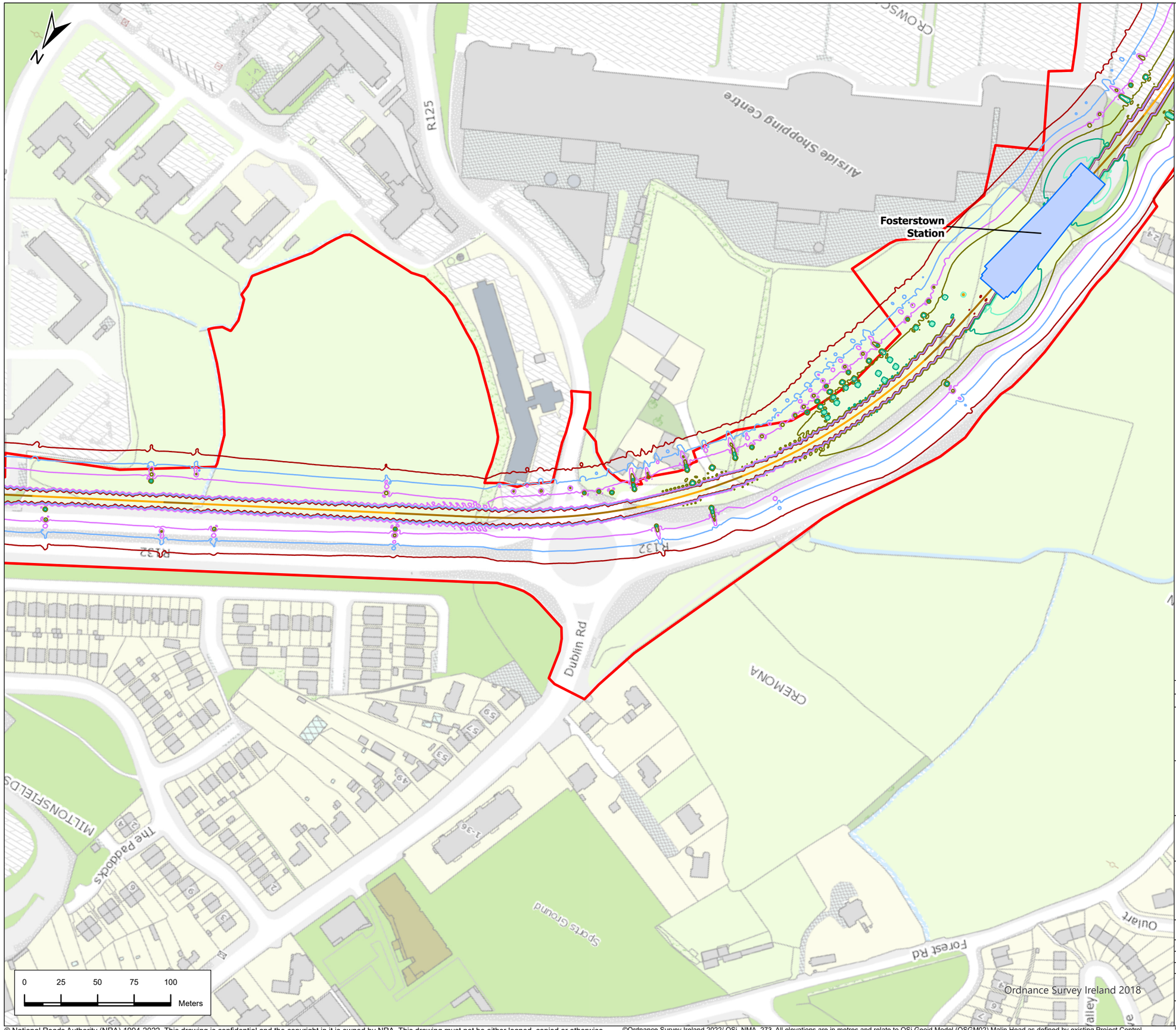
Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 5 of 30

Drawing Status	Final	
Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21125	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment
- Cut & Cover
- Retained Cut
- Station Locations
- Project Boundary

Geographic Split
- AZ1 Northern Section

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

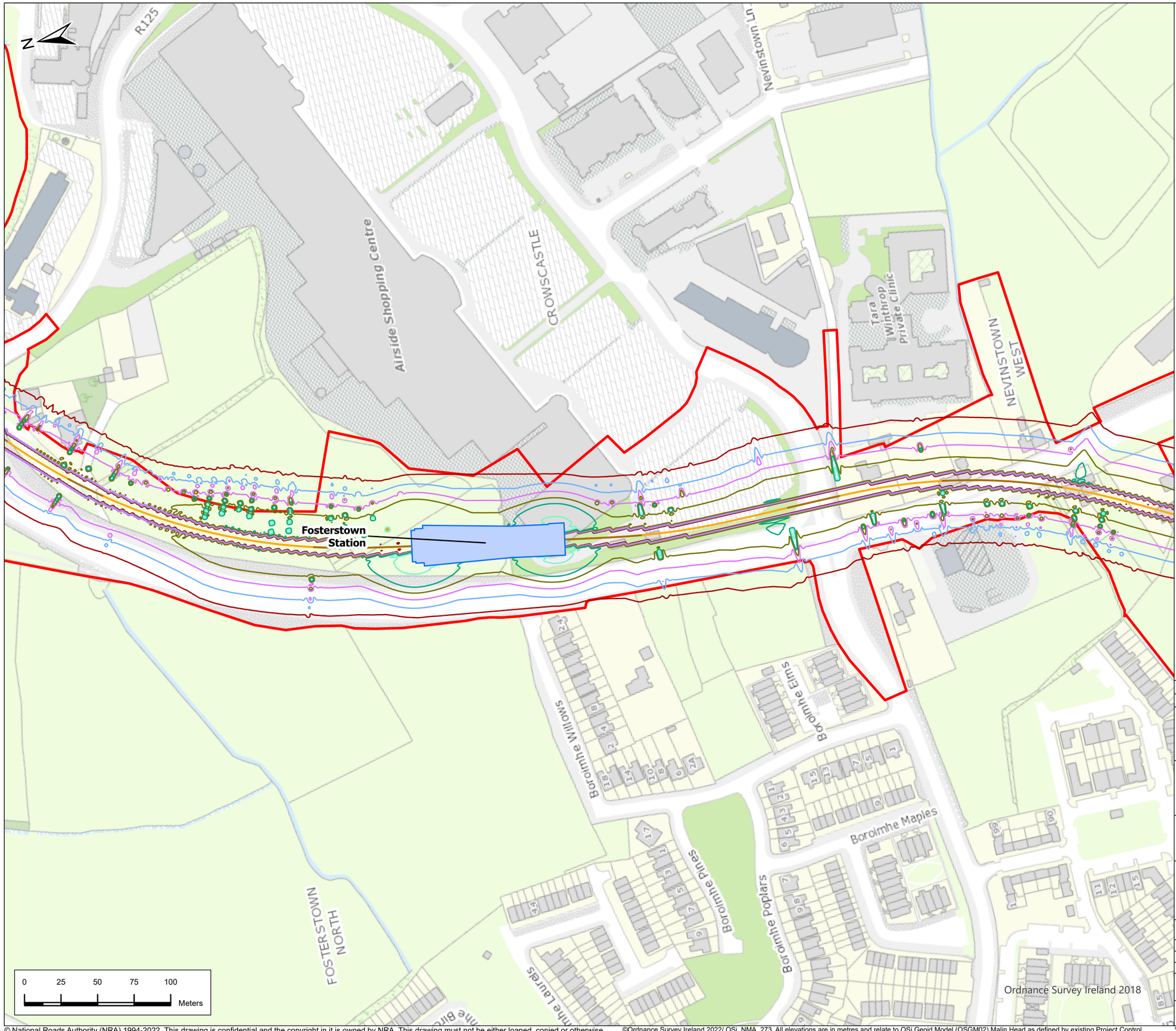
Drawing Title: Figure 20.16 Settlement Contours
Sheet 6 of 30

Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21126	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

Path: \\europe.jacobs.com\Dublin\Data\IR\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment
- Cut & Cover
- Retained Cut
- Station Locations
- Project Boundary

Geographic Split
- AZ1 Northern Section

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 7 of 30

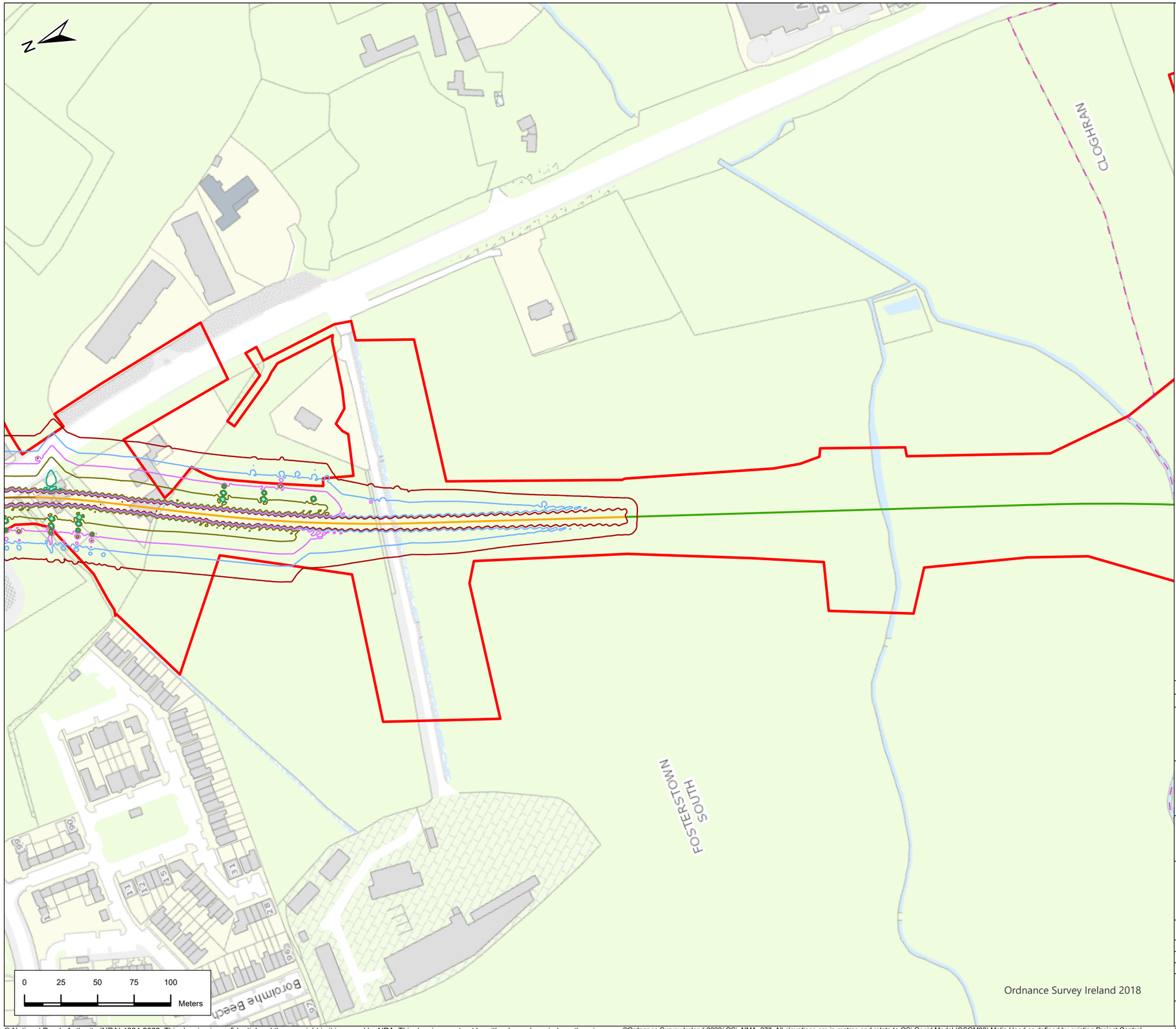
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21127	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx

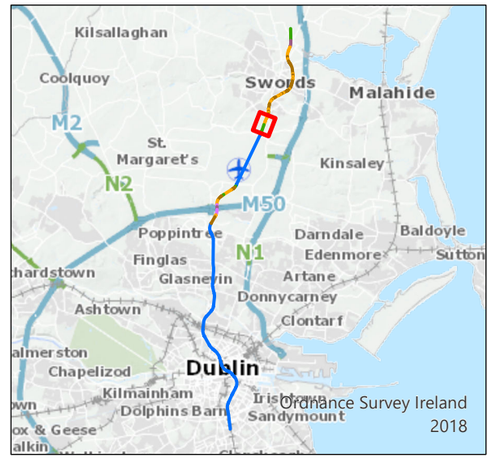


Legend

Alignment
- Cut & Cover
- Retained Cut
- Surface
- Station Locations
- Project Boundary

Geographic Split
- AZ1 Northern Section
- AZ2 Airport Section

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 8 of 30

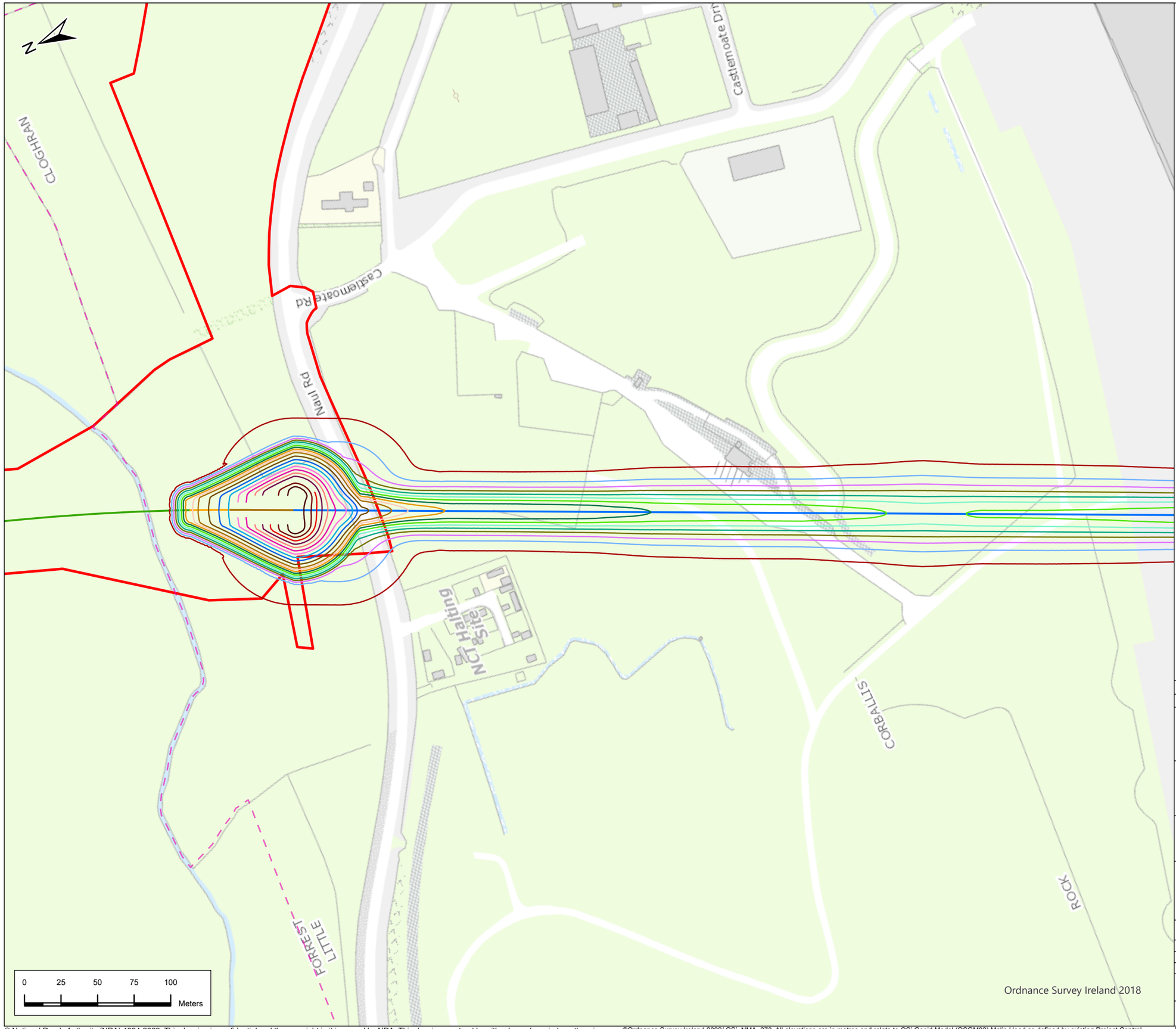
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21128	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

- Cut & Cover
- Retained Cut
- Surface
- Tunnel
- Station Locations
- Project Boundary

Geographic Split

- AZ1 Northern Section
- AZ2 Airport Section

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 9 of 30

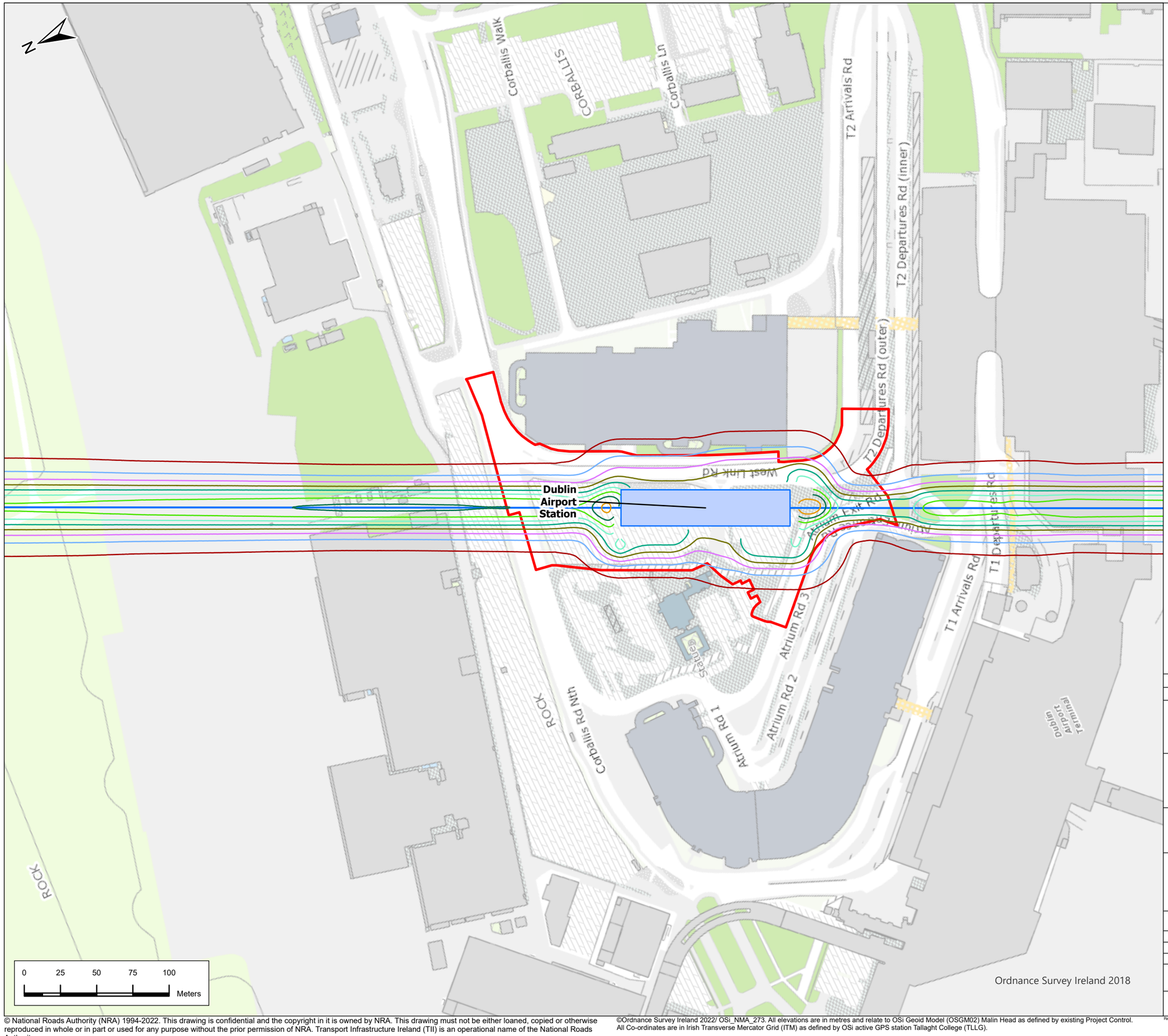
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21129	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\L1 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment
- Tunnel
- Station Locations
- Project Boundary

Geographic Split
- AZ2 Airport Section

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 10 of 30

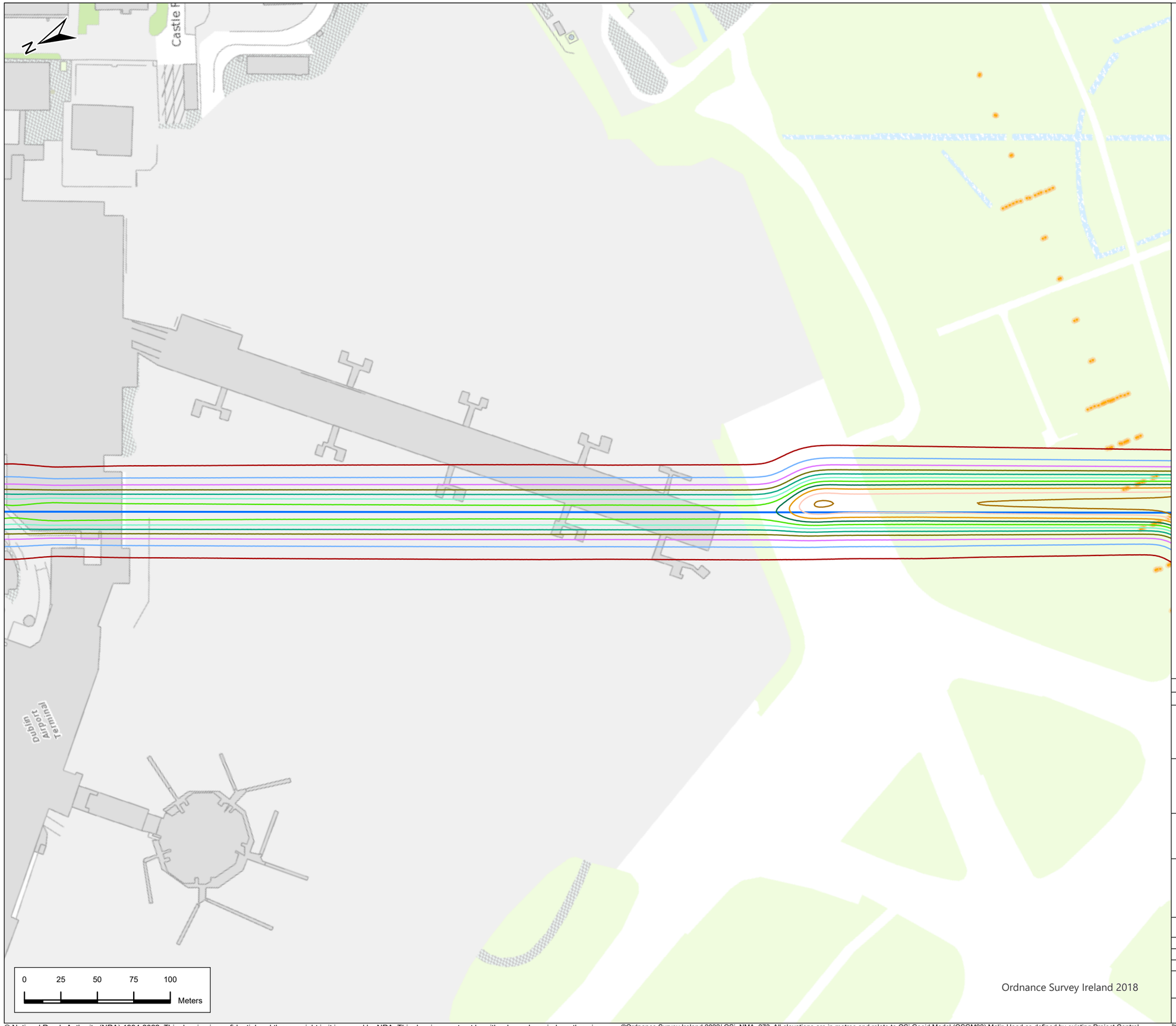
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21130	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JT\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment
- Tunnel
- Station Locations
- Project Boundary

Geographic Split
- AZ2 Airport Section

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

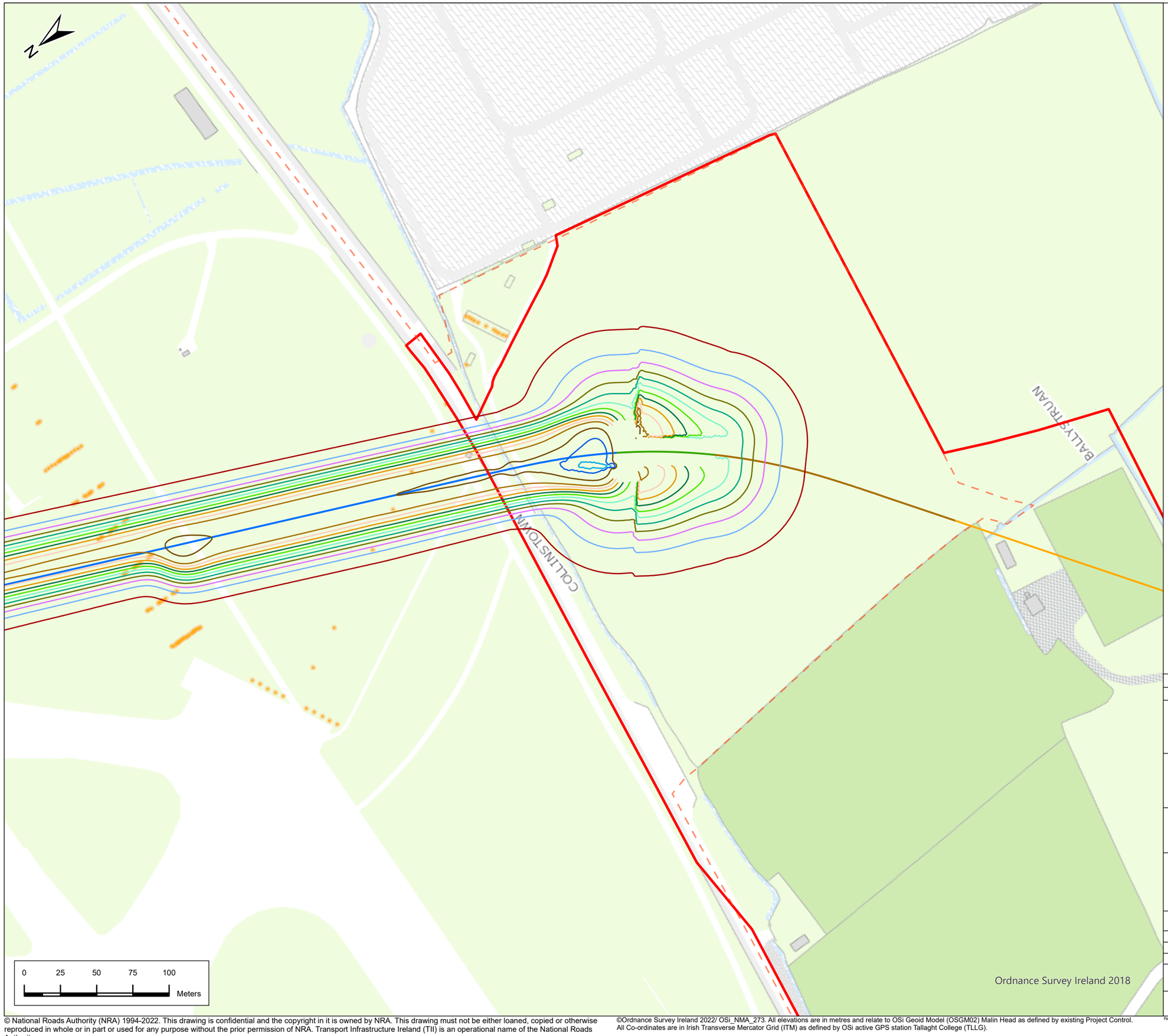
Drawing Title: Figure 20.16 Settlement Contours Sheet 11 of 30

Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21131	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

Path: \\europe.jacobs.com\Dublin\Data\IT\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment
- Cut & Cover
- Retained Cut
- Surface
- Tunnel
- Station Locations
- Project Boundary

Geographic Split
- AZ2 Airport Section
- AZ3 Dardistown to Northwood

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 12 of 30

Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21132	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx

Legend

Alignment

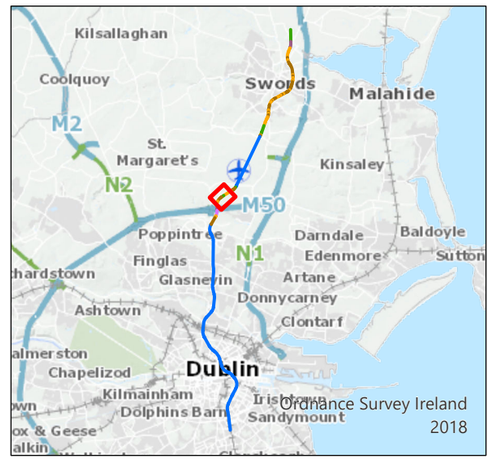
- Cut & Cover
- Retained Cut
- Surface
- Station Locations
- Project Boundary

Geographic Split

- AZ2 Airport Section
- AZ3 Dardistown to Northwood

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 13 of 30

Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21133	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx

Legend

Alignment

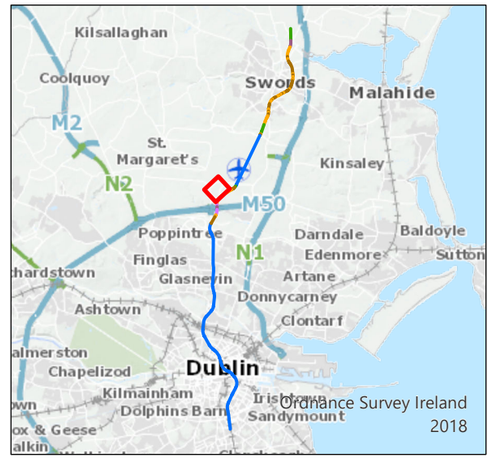
- Cut & Cover
- Surface
- Station Locations
- Project Boundary

Geographic Split

- AZ2 Airport Section
- AZ3 Dardistown to Northwood

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 14 of 30

Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21134	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx

Legend

Alignment

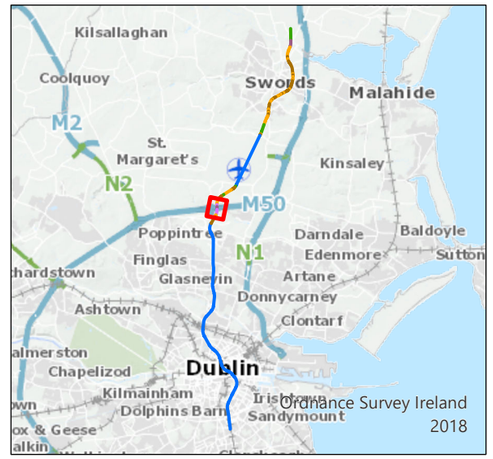
- Cut & Cover
- Incline
- Retained Cut
- Viaduct
- Station Locations
- Project Boundary

Geographic Split

- AZ3 Dardistown to Northwood

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 15 of 30

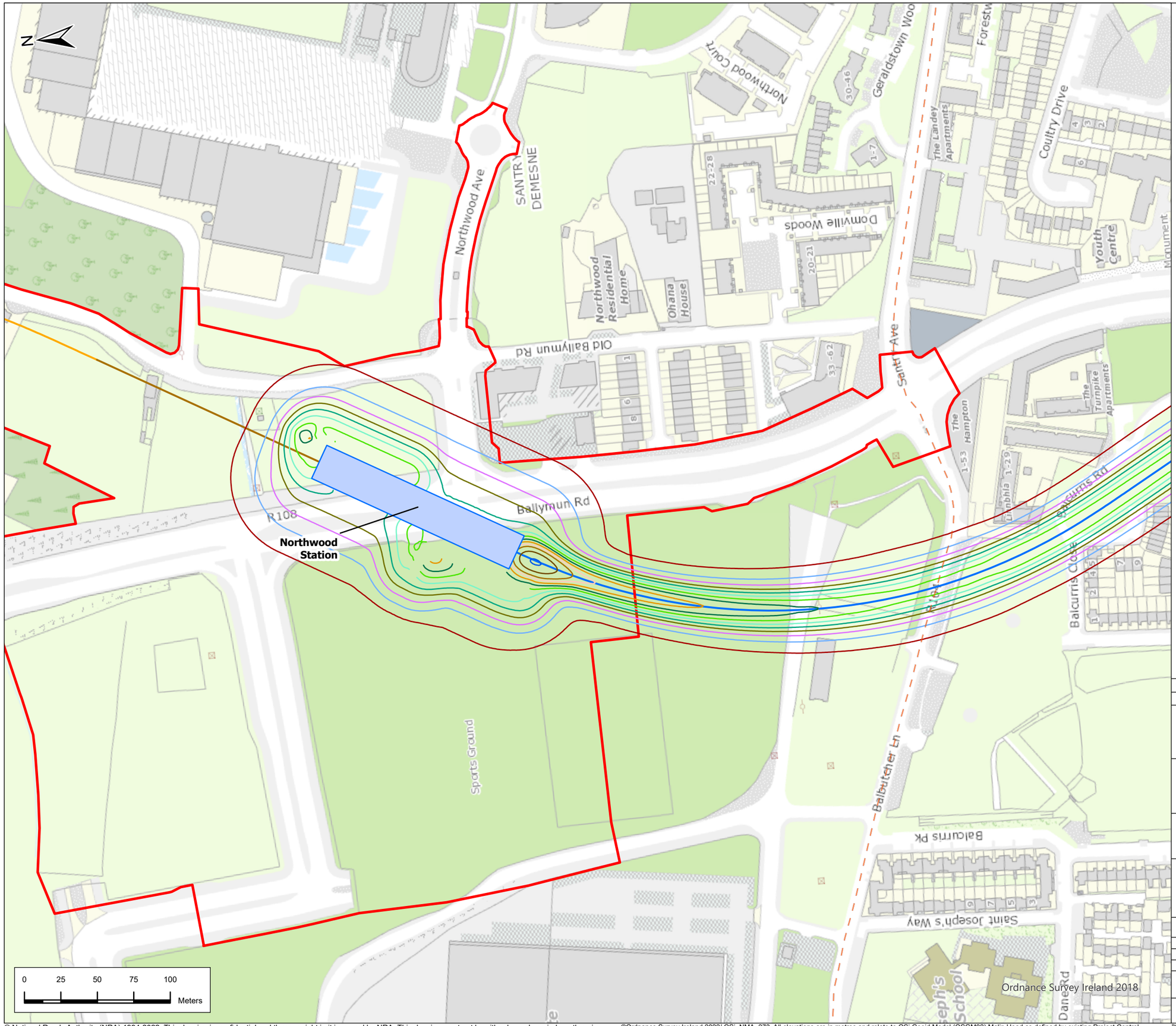
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21135	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx

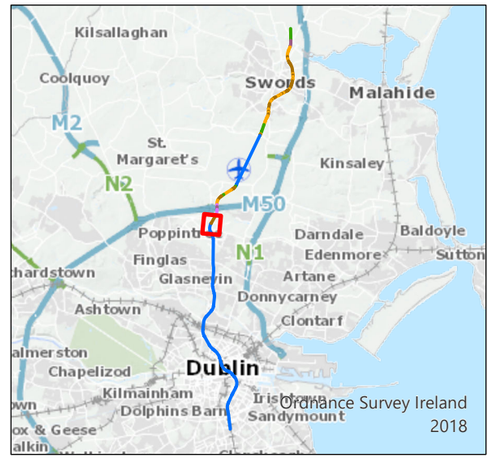


Legend

Alignment
- Cut & Cover
- Retained Cut
- Tunnel
- Station Locations
- Project Boundary

Geographic Split
- AZ3 Dardistown to Northwood
- AZ4 Northwood to Charlemont

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 16 of 30

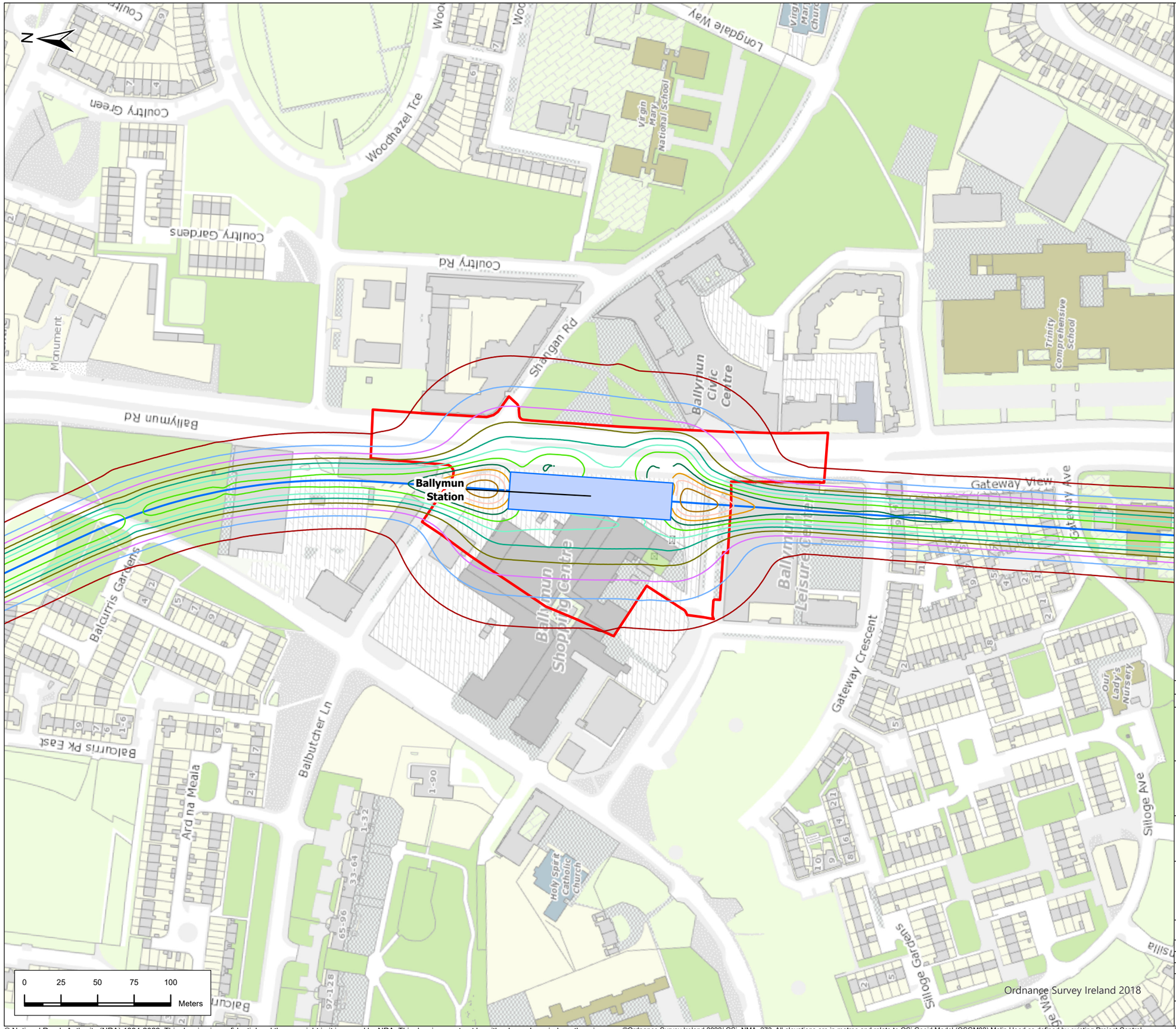
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21136	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\IT\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

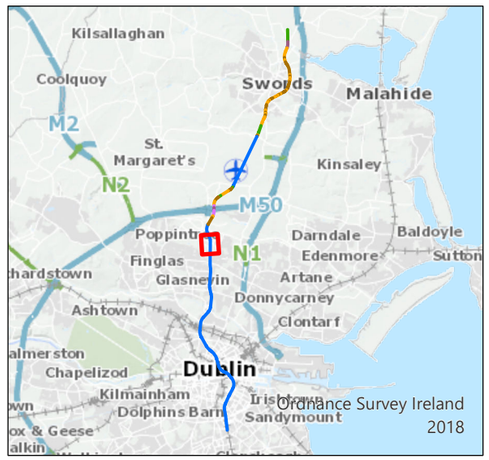
- Tunnel
- Station Locations
- Project Boundary

Geographic Split

- AZ4 Northwood to Charlemont

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 17 of 30

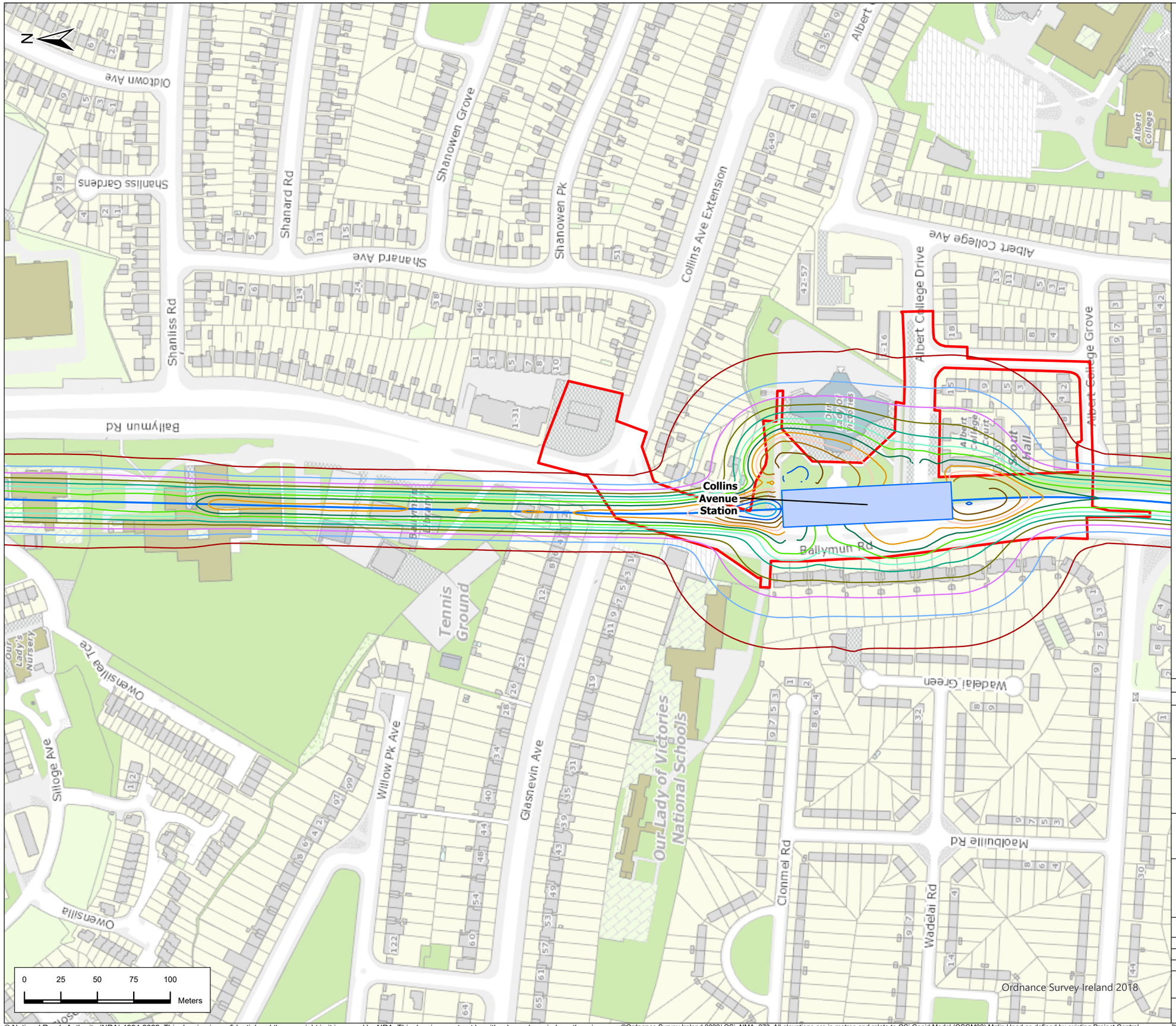
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21137	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

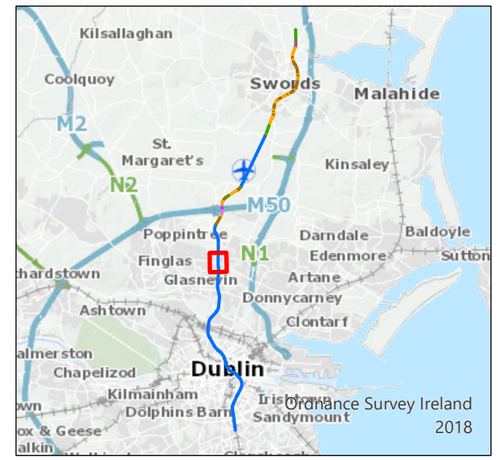
- Tunnel
- Station Locations
- Project Boundary

Geographic Split

- AZ4 Northwood to Charlemont

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title

Figure 20.16 Settlement Contours
Sheet 18 of 30

Drawing Status: Final

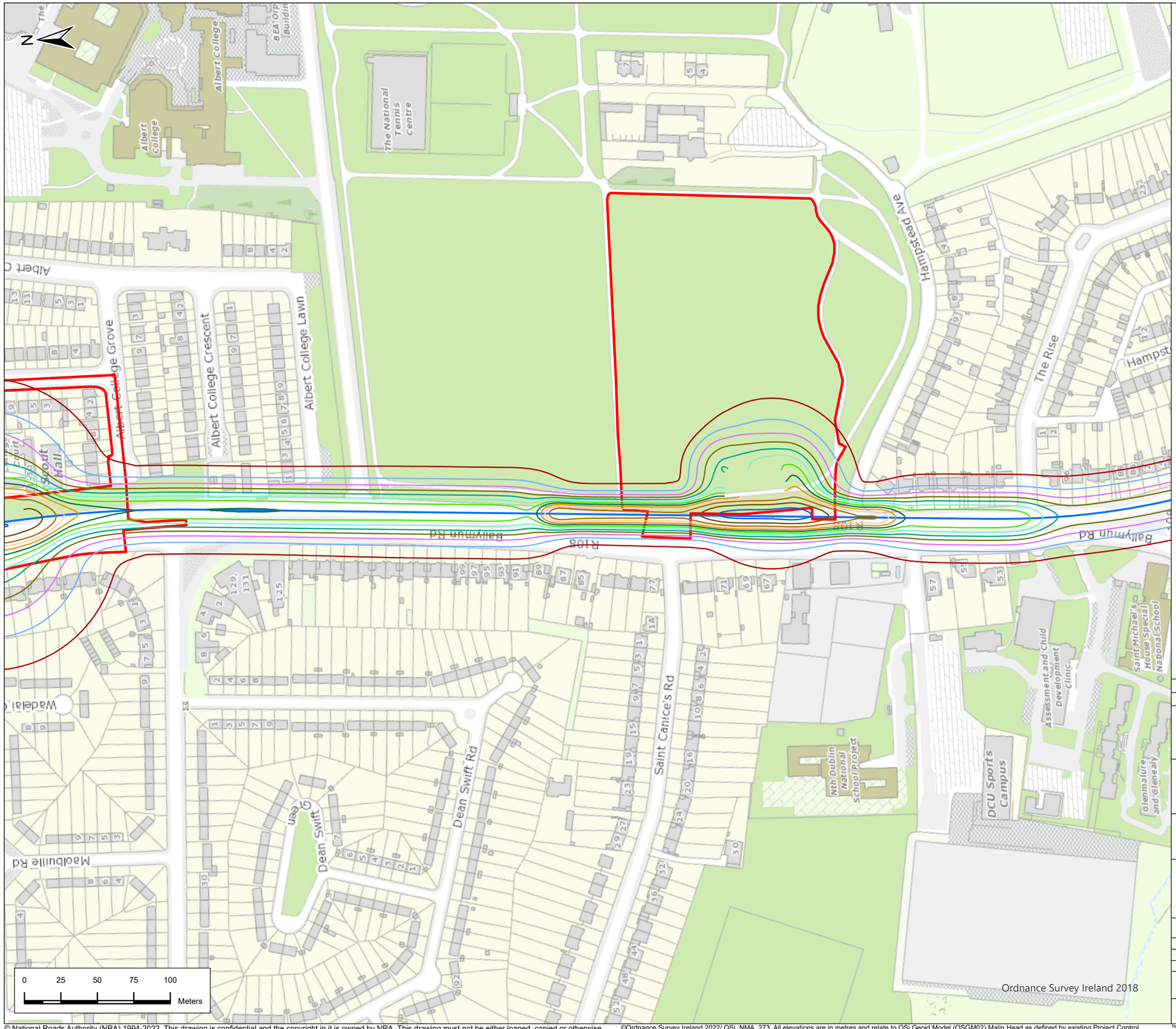
Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		

Drawing No.: ML1-JAI-EIA-ROUT_XX-DR-Y-21138 Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx

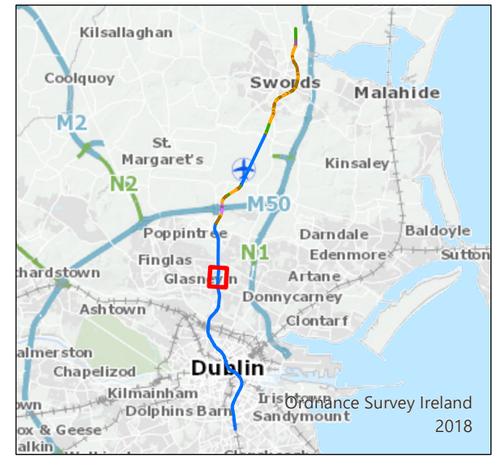


Legend

Alignment
- Tunnel
- Station Locations
- Project Boundary

Geographic Split
- AZ4 Northwood to Charlemont

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 19 of 30

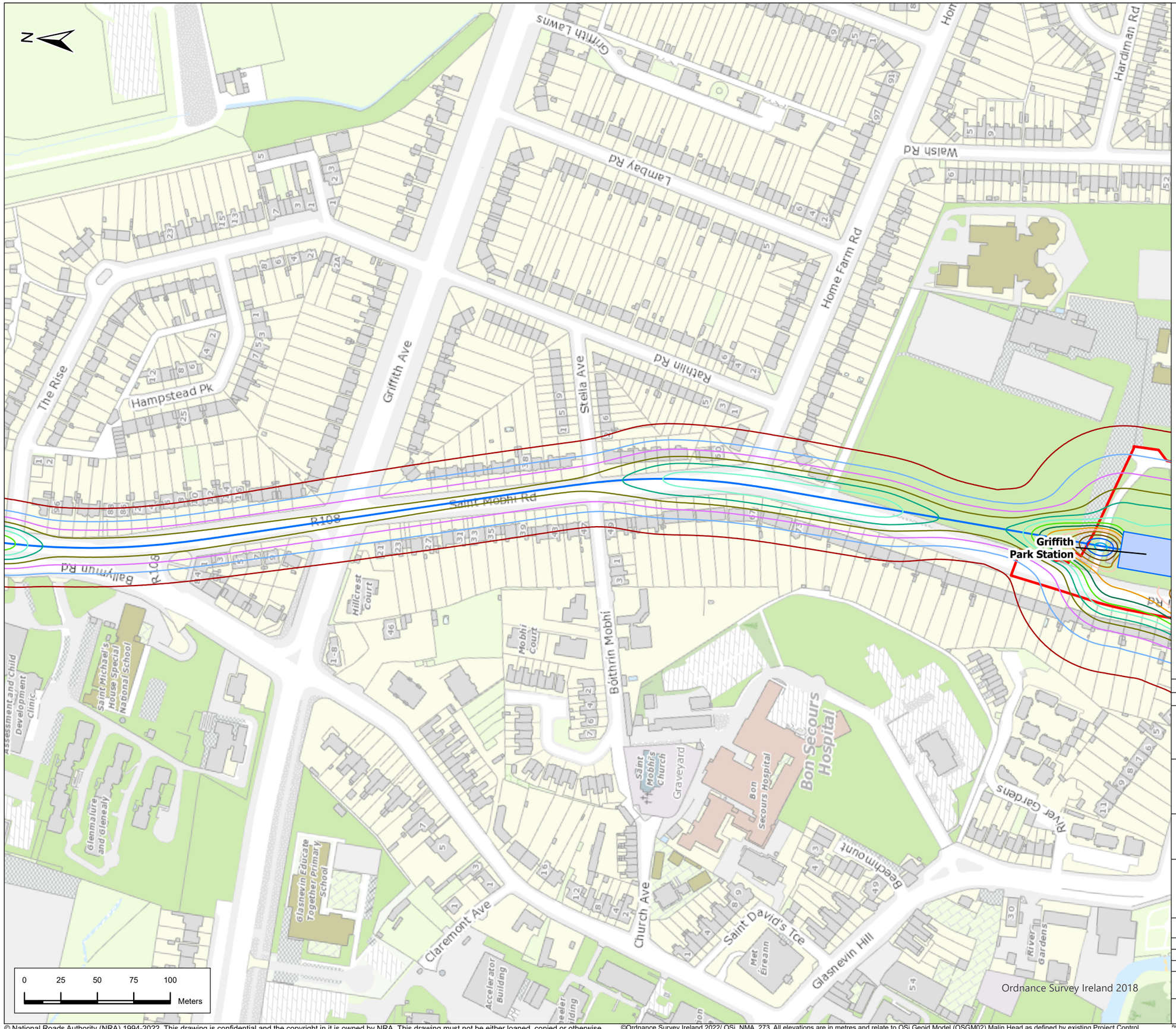
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21139	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\EH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

- Tunnel
- Station Locations
- Project Boundary

Geographic Split

- AZ4 Northwood to Charlemont

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 20 of 30

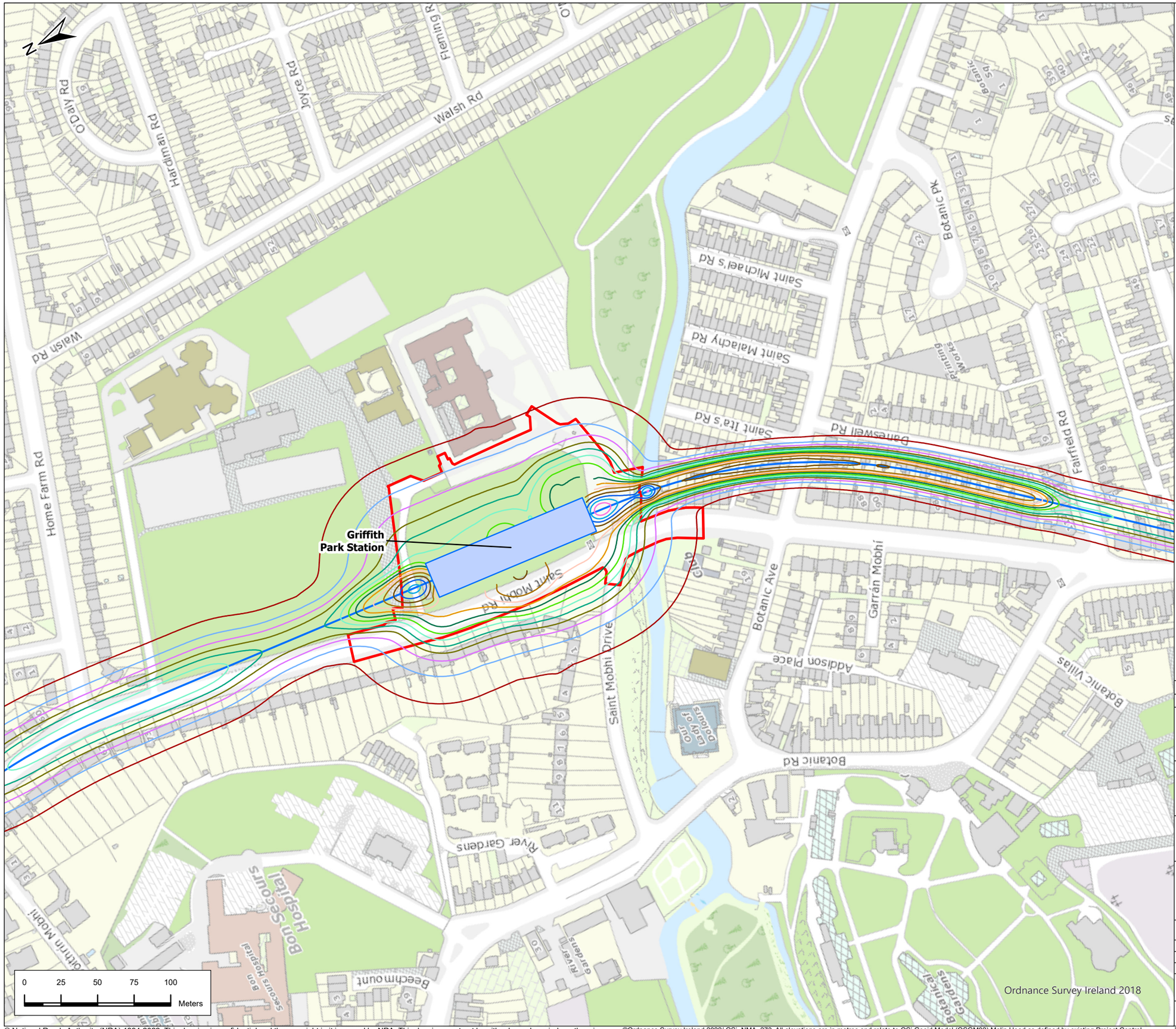
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21140	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

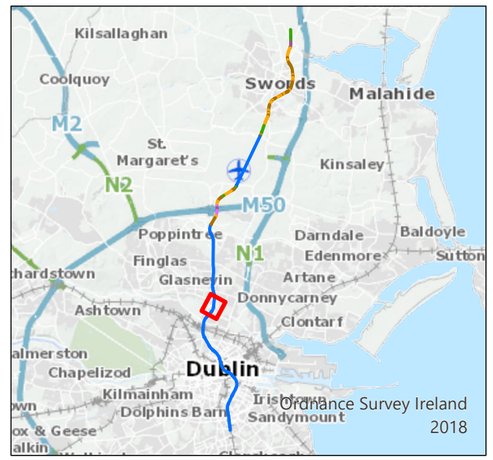
- Tunnel
- Station Locations
- Project Boundary

Geographic Split

- AZ4 Northwood to Charlemont

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: Bonneagar Iompair Eireann, Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 21 of 30

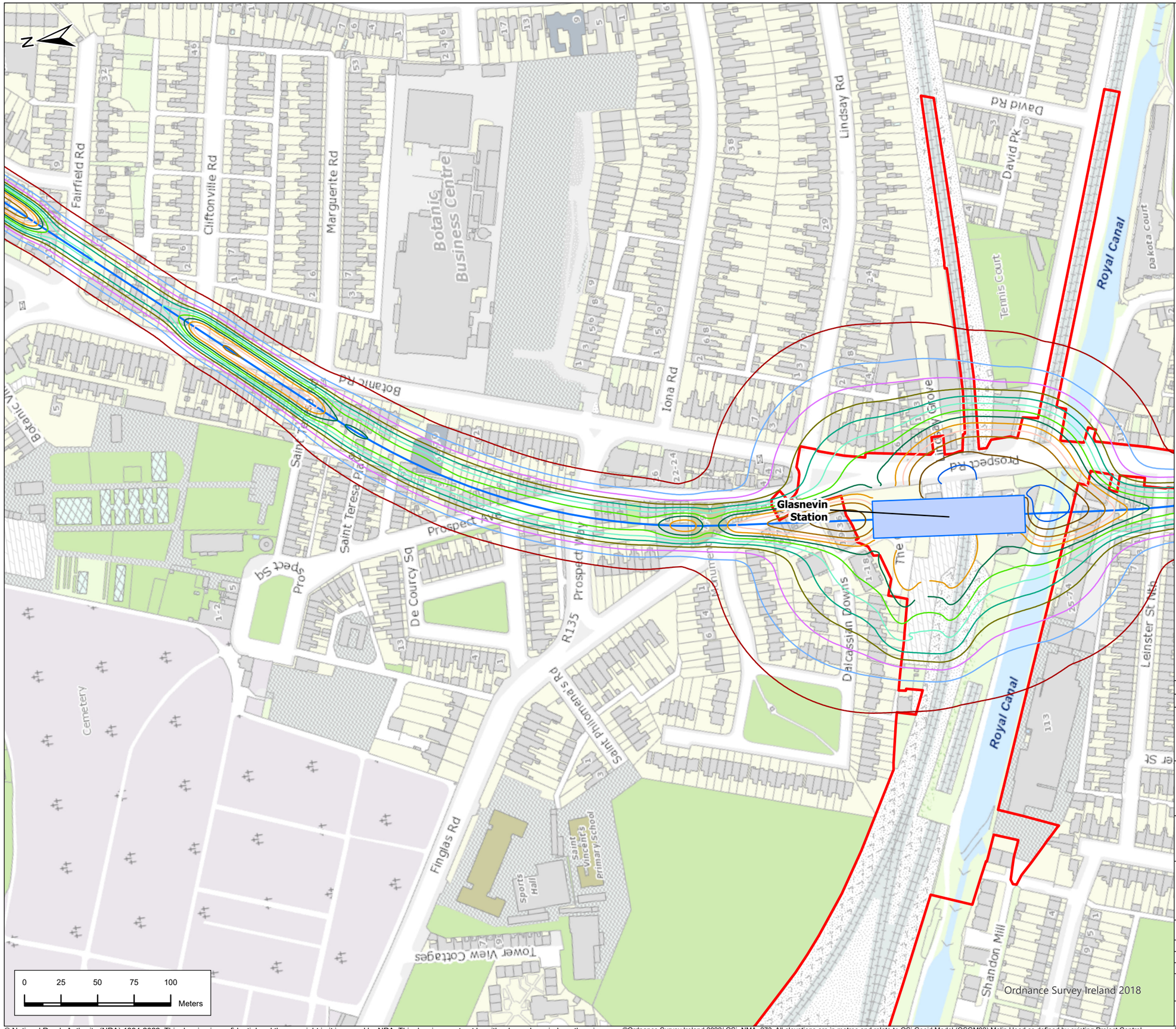
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21141	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\IT\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

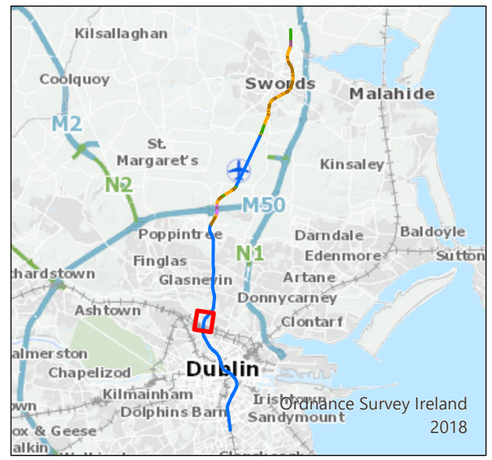
- Tunnel
- Station Locations
- Project Boundary

Geographic Split

- AZ4 Northwood to Charlemont

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 22 of 30

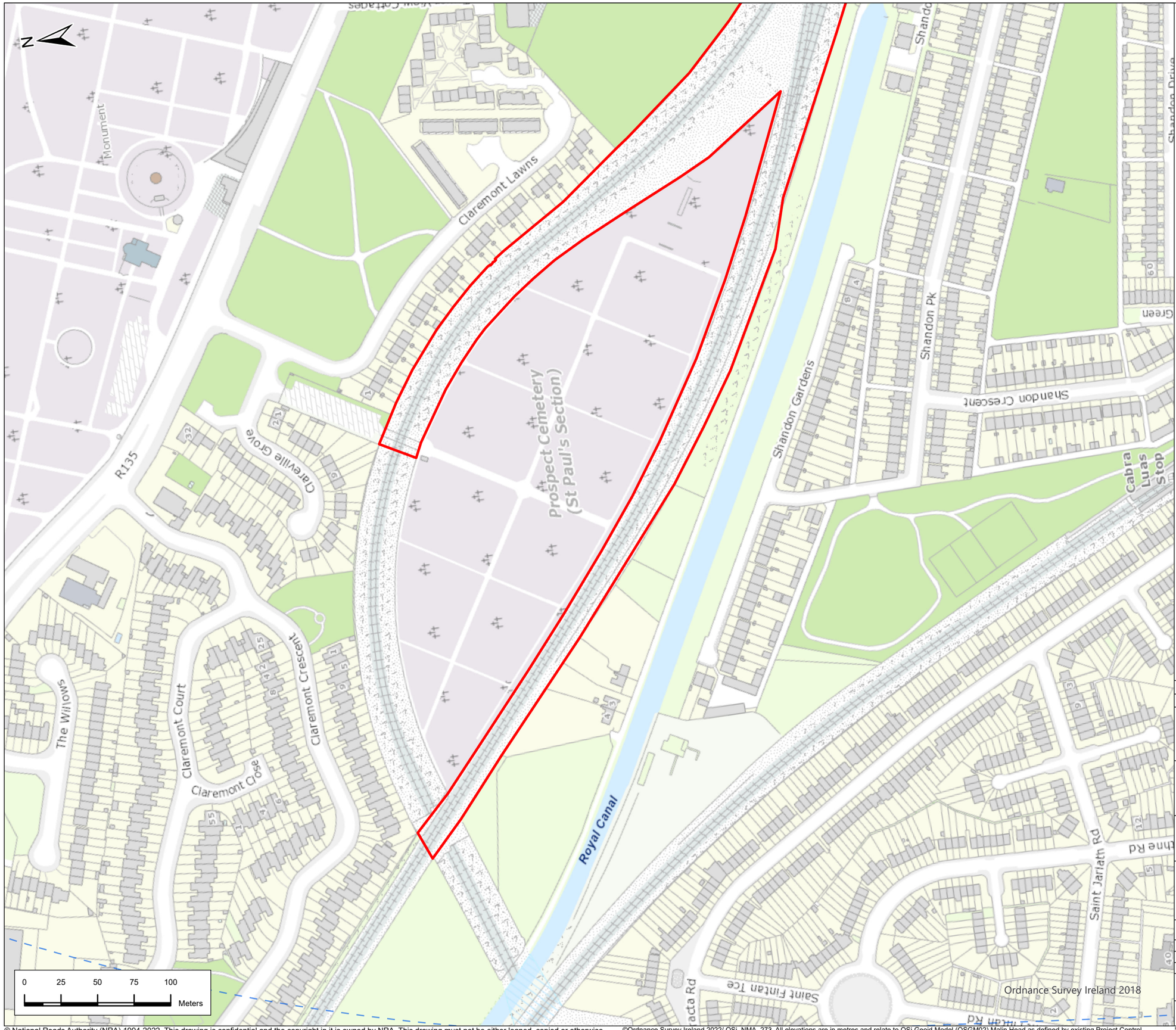
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21142	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\IT\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

- Station Locations
- Project Boundary

Geographic Split

- AZ4 Northwood to Charlemont

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 23 of 30

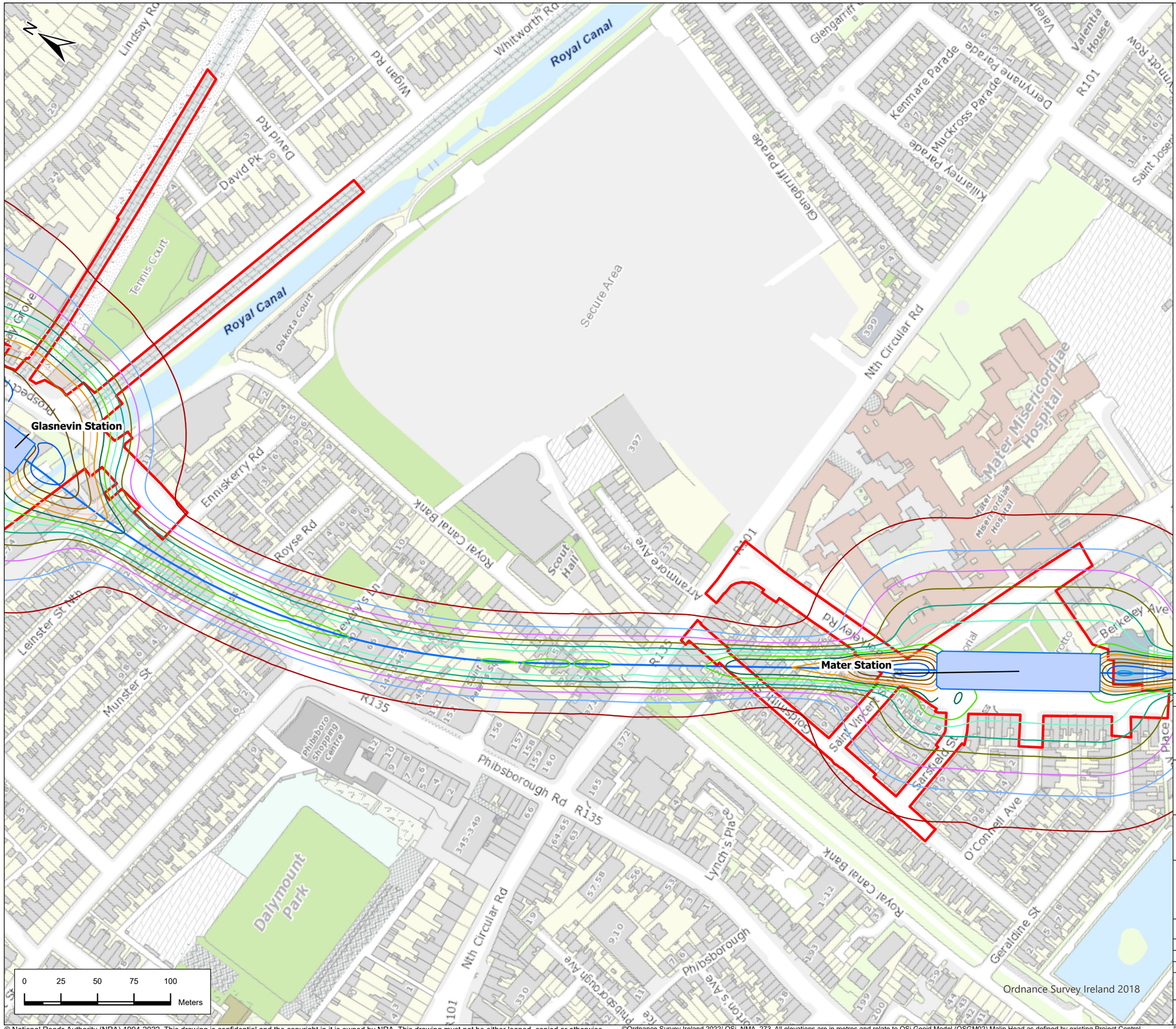
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21143	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx

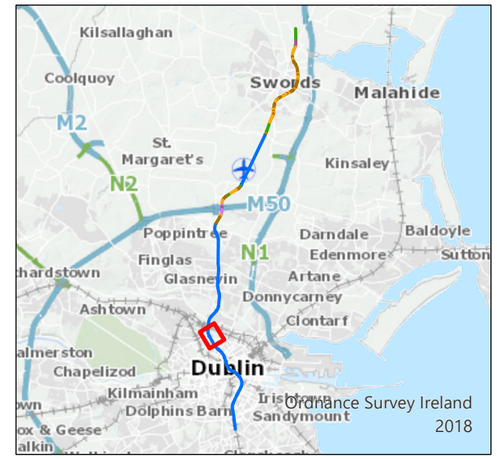


Legend

Alignment
- Tunnel
- Station Locations
- Project Boundary

Geographic Split
- AZ4 Northwood to Charlemont

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 24 of 30

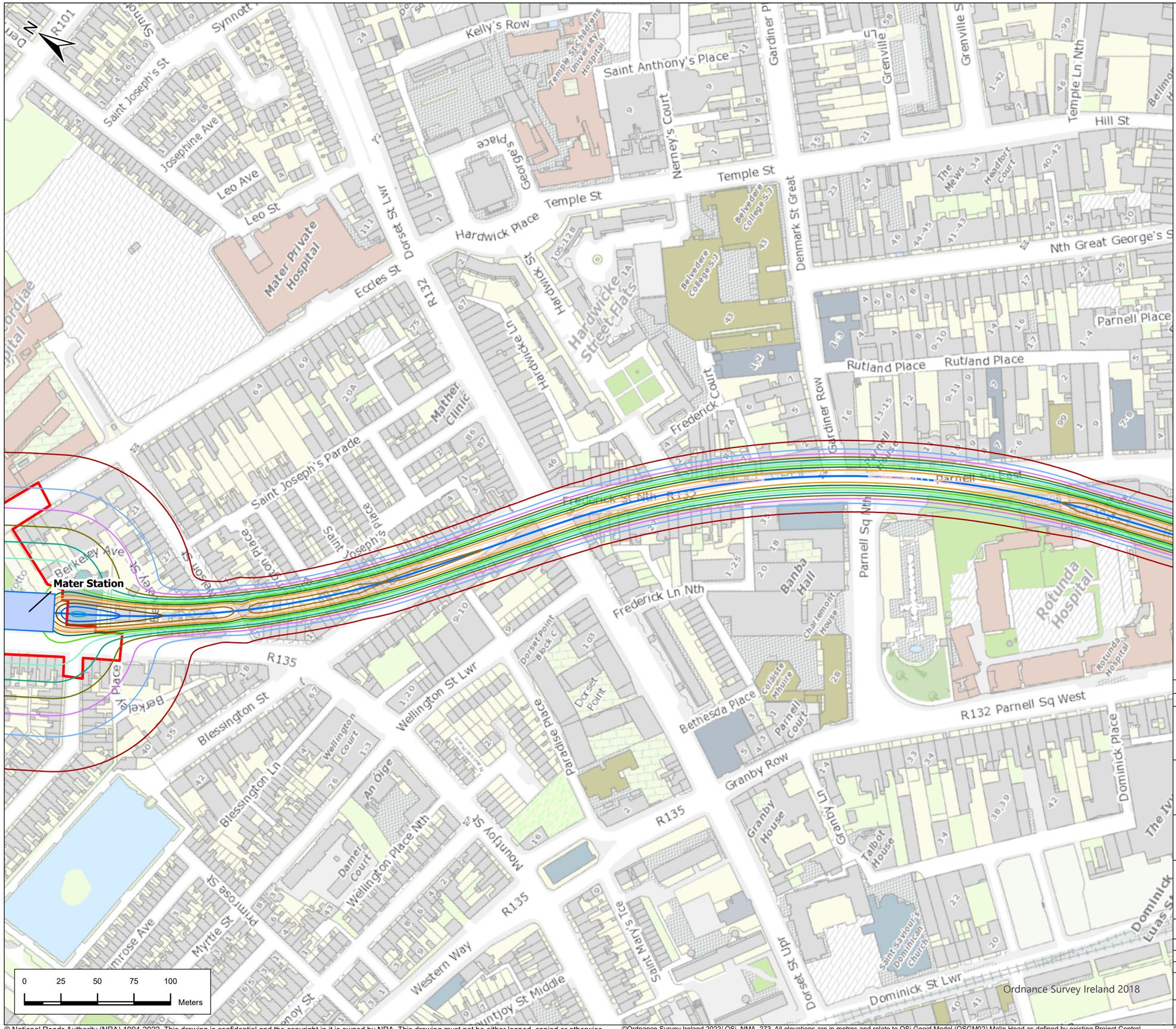
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21144	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\IR\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

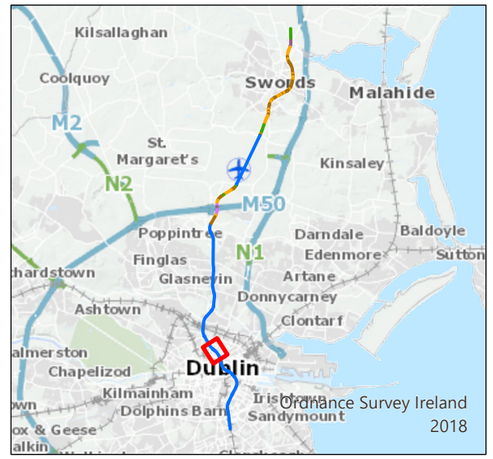
- Tunnel
- Station Locations
- Project Boundary

Geographic Split

- AZ4 Northwood to Charlemont

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 25 of 30

Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21145	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

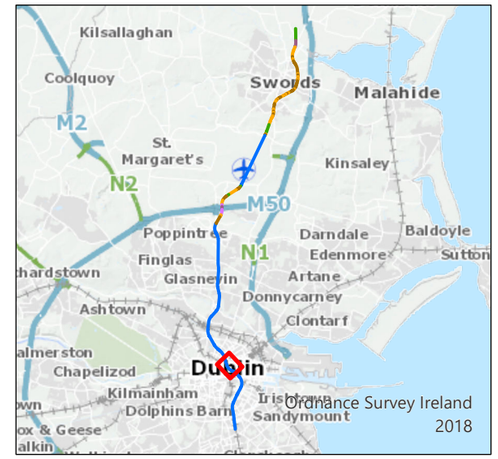
Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx

Legend

Alignment
- Tunnel
- Station Locations
- Project Boundary

Geographic Split
- AZ4 Northwood to Charlemont

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 26 of 30

Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21146	Rev P02

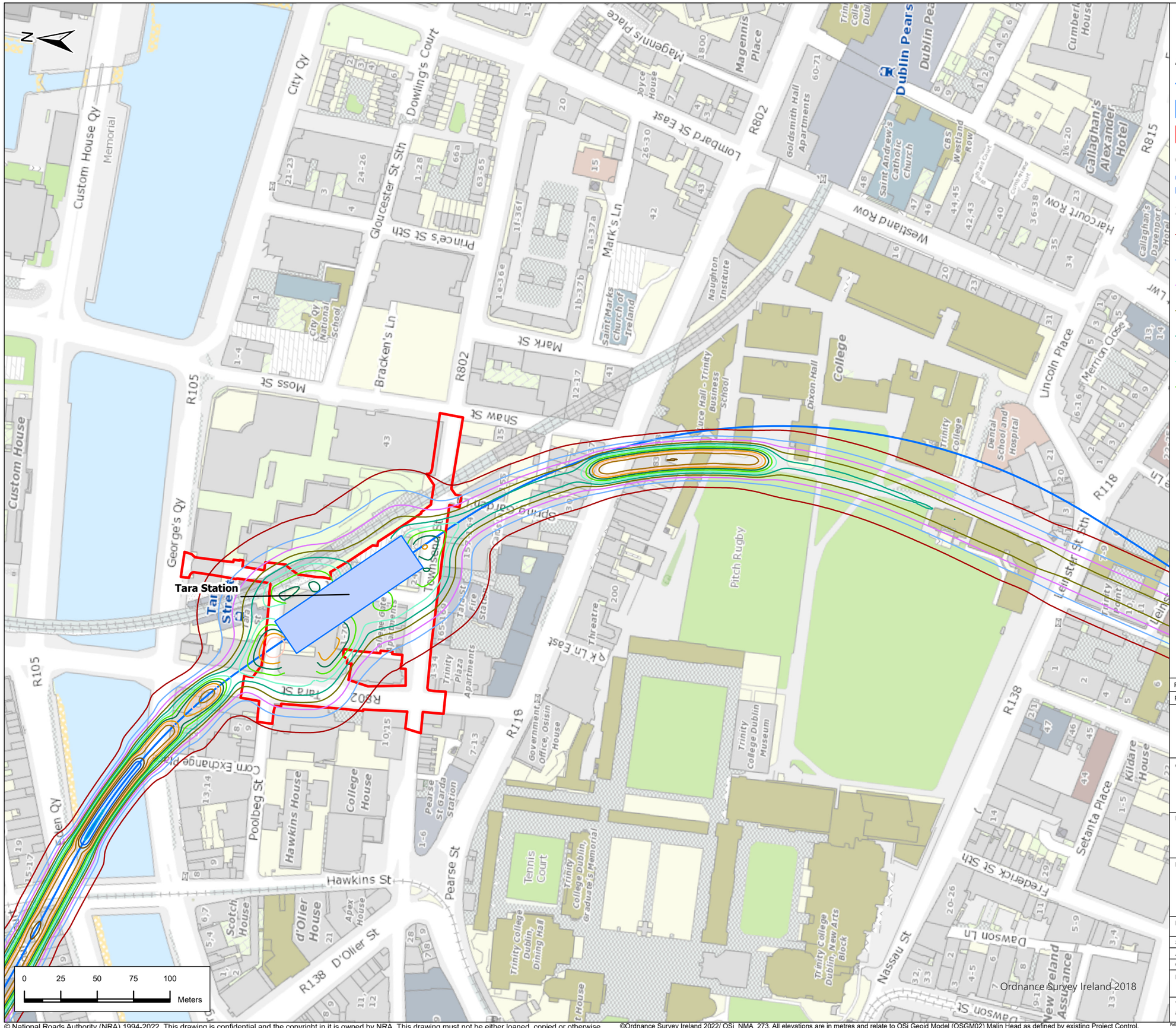
This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

0 25 50 75 100 Meters

Ordnance Survey Ireland 2018

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx

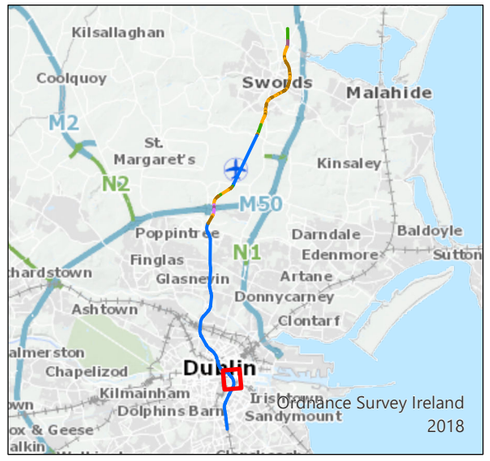


Legend

Alignment
- Tunnel
- Station Locations
- Project Boundary

Geographic Split
- AZ4 Northwood to Charlemont

Settlement Contours
- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 27 of 30

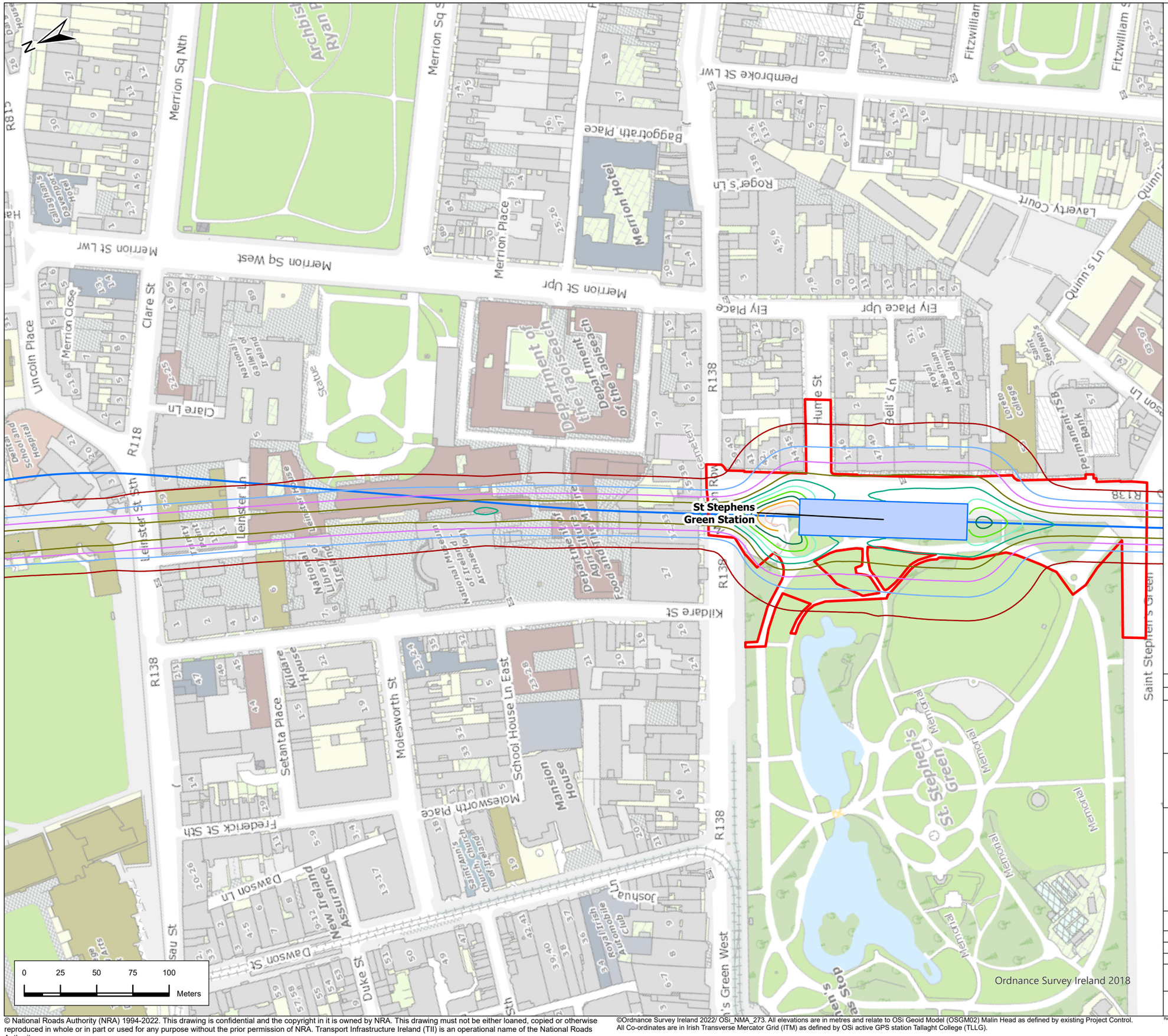
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21147	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

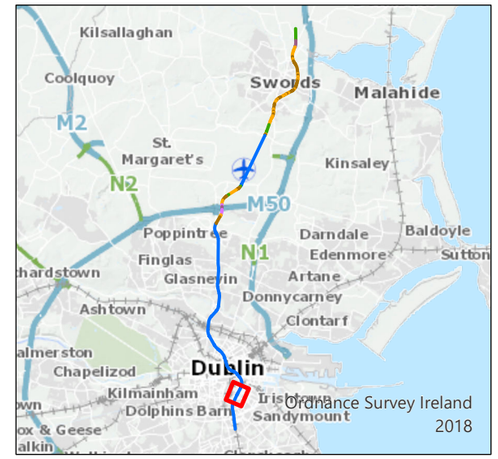
- Tunnel
- Station Locations
- Project Boundary

Geographic Split

- AZ4 Northwood to Charlemont

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours
Sheet 28 of 30

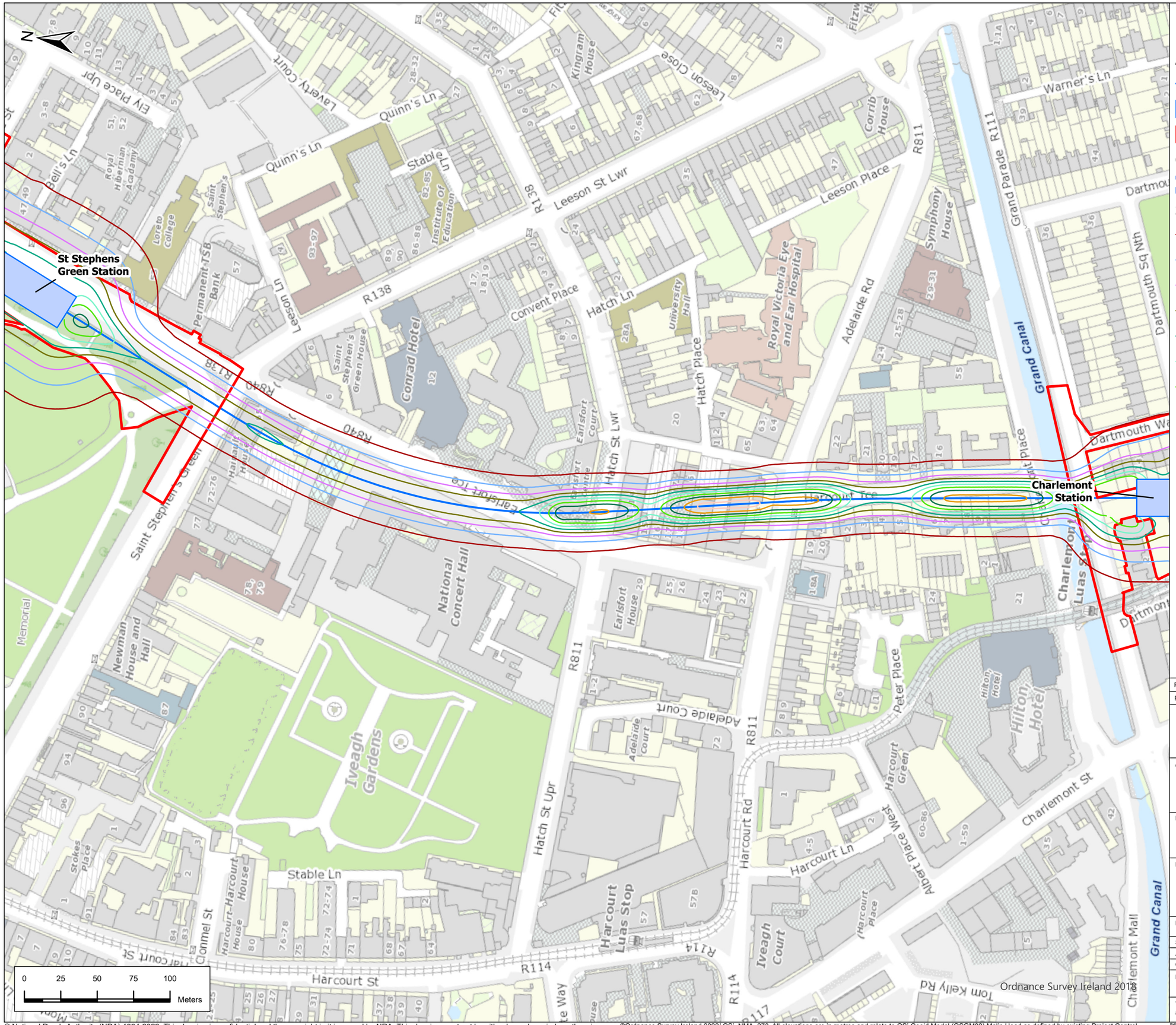
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21148	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\IT\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

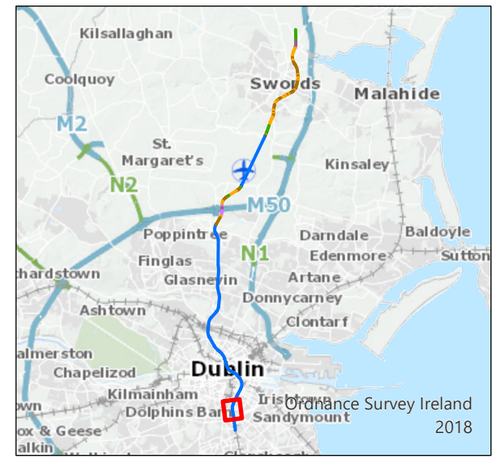
- Tunnel
- Station Locations
- Project Boundary

Geographic Split

- AZ4 Northwood to Charlemont

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Eireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title: Figure 20.16 Settlement Contours Sheet 29 of 30

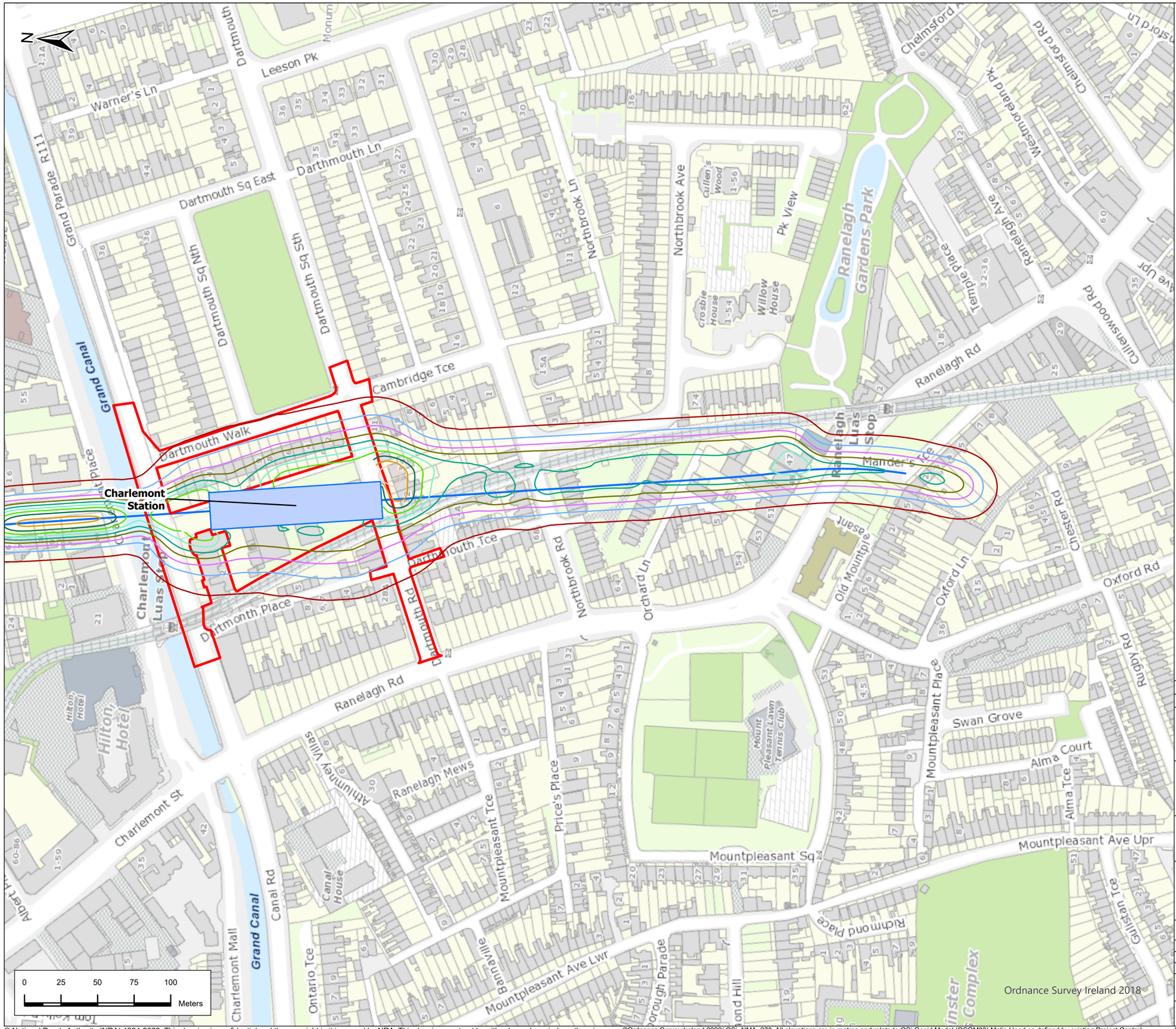
Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21149	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\IT\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx



Legend

Alignment

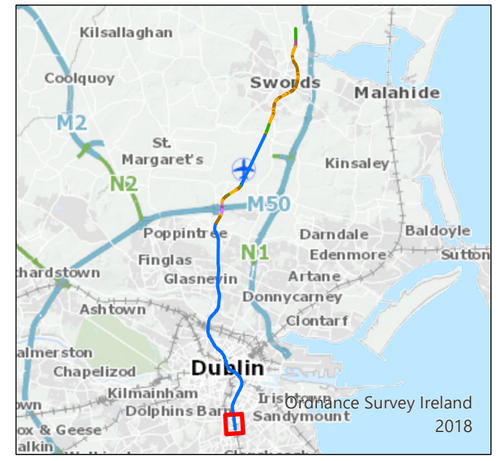
- Tunnel
- Station Locations
- Project Boundary

Geographic Split

- AZ4 Northwood to Charlemont

Settlement Contours

- 1mm
- 5mm
- 10mm
- 15mm
- 20mm
- 25mm
- 30mm
- 35mm
- 40mm
- 45mm
- 50mm
- 60mm
- 70mm
- 80mm
- 90mm
- 100mm
- 110mm
- 120mm
- 130mm
- 140mm
- 150mm



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P02	8/12/2022	Final Issue	JL	RH	RH	NC

JACOBS IDOM

Client: TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Project: METROLINK

Drawing Title

Figure 20.16 Settlement Contours
Sheet 30 of 30

Drawing Status: Final

Scale @ A3	1:2,500	DO NOT SCALE
Jacobs No.	32108600	
Client No.		
Drawing No.	ML1-JAI-EIA-ROUT_XX-DR-Y-21150	Rev P02

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

©Ordnance Survey Ireland 2022/ OSi_NMA_273. All elevations are in metres and relate to OSi Geoid Model (OSGM02) Malin Head as defined by existing Project Control. All Co-ordinates are in Irish Transverse Mercator Grid (ITM) as defined by OSi active GPS station Tallaght College (TLLG).

Path: \\europe.jacobs.com\Dublin\Data\JI\Sustainable Solutions\Metro North\11 - Mapping\Working\EIAR_Drawings\CH 20 - Fig 20.16 Settlement Contours.aprx

Appendix D. Subsidence Damage Assessment Methodology for Buildings due to Tunnelling and Other Associated works

1. Introduction

1.1 The construction of Dublin MetroLink tunnels, station boxes, shafts, retained cutting will all lead to ground movements near the ground surface. The amount of ground movements will depend on several factors including

- the depth and volume of the works below ground;
- the ground conditions;
- the method of construction;
- the presence and nature of buildings;
- and the type of foundations.

1.2 The magnitude of the ground movement will vary across the footprint of the buildings resulting in differential ground movement which has the potential to damage buildings and other infrastructure, including utilities. If damage were to occur, it could range from small internal cracks in plaster to effects on the structural integrity of the building, although in most cases there is no discernible effect on the structure itself. Depending on the level of risk either

- no action will be required (i.e. the building fall outside of the 1mm contour);
- buildings will be monitored during construction;
- or special protective measures will be implemented to protect the buildings.

2. Settlement Impact Assessments

2.1 The industry standard three-phased approach is proposed to assess the buildings that may be affected by the structural excavations carried out by the Contractor which is similar to the process adopted for other major tunnelling projects including Crossrail in London or HS2 in the UK.

PHASE 1

2.2 The Phase 1 assessment is based on “green-field” site conditions. This means that the interaction of the building and its foundations on the shape of settlement profile is ignored.

2.3 For bored tunnels, the settlement predictions for “green-field” site conditions are based on empirical methods described by O’Reilly and New (1982) using parameters for ground loss determined from case histories considering the method of tunnelling and ground conditions. For the Phase 1 assessment, the volume loss for the tunnels within the superficial material and rock strata will be taken as 1.5% and 0.75%

respectively. The tunnel is considered in rock when there is at least half-a-tunnel diameter rock cover above the tunnel crown, otherwise tunnel is assumed to be in superficial material.

2.4 For excavations comprising shafts, station boxes and retained cuttings, a conservative methodology for predicting settlements has been developed based on case history data presented in CIRIA 760.

2.5 Where the predicted settlement from bored tunnels and from other excavations referred above is less than 10mm and the predicted ground slope is less than 1/500, those buildings are not subject to further assessment. Those for which predicted settlement is 10mm or more, or for which predicted ground slope is 1/500 or more, are subject to a Phase 2 assessment.

2.6 However, despite the above screening process, any buildings within the 1mm contour will be subject to a Phase 2 assessment if:

(a) it is on shallow foundations and is within a distance from a retained cutting, shaft or box equal to the excavated depth of superficial deposits or 50% of the total excavation depth, whichever is the greater. In this context, superficial deposits are taken to be soils above the rockhead level;

(b) it has a foundation level deeper than 4m, or (in the case of a bored tunnel) greater than 20% of the depth to tunnel axis;

(c) it is a Protected/Prominent Buildings; or

(d) any 'sensitive' buildings that might need further assessment to determine whether any protective works required.

PHASE 2

2.7 In Phase 2, the settlement calculated for "green-field" conditions are imposed on buildings, i.e. it is assumed that buildings behave completely flexible ignoring the building stiffness. In addition, the deformation due to horizontal ground movement is considered (analysed using for example CIRIA 760 for diaphragm wall installation to determine the 'green-field' horizontal deformation and closed form solutions for the tunnel induced lateral movement). This is still a conservative assumption as in reality the buildings will modify the settlement effects thus reducing the potential for damage.

2.8 The potential for damage in this Phase 2 assessment is classified using the procedure described by Burland (1995) and Mair et al (1996). Each building is categorised into one of six damaged categories by reference to maximum tensile strain as described in column 2 of Table 1. This classification assumes a simple brick masonry construction, whereas other forms of construction, such as framed buildings, are more robust.

2.9 This assessment is only sufficiently informative for buildings with relatively shallow foundations.

2.10 Buildings assessed to be in Damage Category 0, 1 or 2 after the Phase 2 assessment are not subject to further assessment. All buildings which are placed in Damage Category 3 or above in the Phase 2 assessment are subject to a Phase 3 assessment.

2.11 However, despite the above classification of the Damage Category level, all buildings will be subject to a Phase 3 assessment if:

(a) it is on shallow foundations and is within a distance from a retained cutting, shaft or box equal to the excavated depth of superficial deposits or 50% of the total excavation depth, whichever is the greater. In this context, superficial deposits are taken to be soils above the rockhead level;

(b) it has a foundation level deeper than 4m, or (in the case of a bored tunnel) greater than 20% of the depth to tunnel axis;

(c) it is a Protected Structure; or

(d) any 'sensitive' buildings that might need further assessment to determine whether any protective works required.

PHASE 3

2.12 In Phase 3 of the assessment procedure, each building is considered individually in contrast to the first 2 phases where the area of interest is analysed generically.

2.13 The Phase 3 assessment consists of several sub-steps (referred to as "Iterations"), each refining the building and tunnel model to a higher degree. In this phase, both the magnitude of strain developing in the building and the validity of the standard risk categories (which are originally based on masonry structures) are reappraised. In the first Iteration, a similar model that was used for the Phase 2 assessment will be adopted. The model is then successively refined in the subsequent iterations. If required, the tunnel-excavation-ground-building interaction is modelled using Finite Element / Finite Difference techniques with appropriate level of sophistication to verify whether a reduction in the category of damage to an acceptable level is feasible.

2.14 A structural survey will be undertaken to determine the structural form and condition of the building where necessary for the assessment. In every case where a building is subject to a Phase 3 assessment, a desktop structural appraisal by a qualified structural engineer will be carried out for the purpose of confirming the likely structural behaviour and determining whether a detailed structural survey would be required.

2.15 As a result of the Phase 3 assessment, the risk category of the building is reassessed, the requirement for any protective works is established for implementation. Appropriate instrumentation and monitoring strategy will also be developed. These details will be included in the building damage assessment report.

3. References

Burland, J.B., Broms, B.B., & de Mello, V.F.B. (1977). Behaviour of foundations and structures. Pages 495-546 of: Proc. 9th Int. Conf. Soil Mech. and Found. Eng., vol. 2.

Burland, J.B. (1995). Invited Special Lecture: Assessment of risk of damage to buildings due to tunnelling and excavation. 1st Int. Conf. on Earthquake Geotechnical Engineering, Tokyo, Vol 3; 1189-1201.

O'Reilly, M.P. and New, B.M. (1982). Settlements above tunnels in the United Kingdom – their magnitude and prediction. Tunnelling '82. Ed Jones, M.J. pp 173-181. London, IMM.

Rankin, W.J. (1988). Ground movements resulting from urban tunnelling: predictions and effects. Pages 79-92 of: Engineering geology of underground movements. The Geological Society, London.

Mair, R.J., Taylor, R.N. and Burland, J.B. (1996). Prediction of ground movements and assessment of risk of building damage due to bored tunnelling. In: Proc. Of the Int. Symp. On Geotech. Aspects of Underground Construction in Soft Ground, 713-718, Balkema, Rotterdam.

Mair, R.J. (2001). Theme Lecture, Research on tunnelling-induced ground movements and their effects on buildings – Lessons from the Jubilee Line Extension. Proceedings of the international conference held at Imperial College, London, UK, on 17–18 July 2001

TABLE 1

Building Damage Classification[1]				
1 Risk Category	2 Max Tensile Strain %	3 Description of Degree of Damage	4 Description of Typical Damage and Likely Form of Repair for Typical Masonry buildings	5 Approx[2] Crack Width (mm)
0	0.05 or less	Negligible	Hairline cracks.	
1	More than 0.05 and not exceeding 0.075	Very Slight	Fine cracks easily treated during normal redecorations. Perhaps isolated slight fracture in building. Cracks in exterior brickwork visible upon close inspection.	0.1 to 1
2	More than 0.075 and not exceeding 0.15	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible; some repointing may be required for weather-tightness. Doors and windows may stick slightly.	1 to 5
3	More than 0.15 and not exceeding 0.3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Repointing and possibly replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather tightness often impaired.	5 to 15 or a number of cracks greater than 3
4	More than 0.3	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and door frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted.	15 to 25 but also depends on number of cracks
5		Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require shoring. Windows broken by distortion. Danger of instability.	Usually greater than 25 but depends on number of cracks

Notes

The table is based on the work of Burland et al (1977) and includes typical maximum tensile strains for the various damage categories (column 2) used in phase 2 settlement analysis.

Crack width is only one aspect of damage and should not be used on its own as a direct measure of it.

Appendix E. Key Assumption Register

No.	Assumption Description
1	For the greenfield Phase 1 settlement assessment works, the following volume loss values have been adopted for the tunnelling works: a) TBM works within superficial material (soft ground) or in rock with less than half-a-diameter rock cover: 1.5% b) TBM works within rock with greater than half-a-diameter rock cover: 0.75% c) Non-TBM works, the corresponding values have been taken as 50% more than that of TBM works.
2	For the refined Phase 2a building damage assessment works, the following volume loss values have been adopted for the tunnelling works: a) TBM works within superficial material (soft ground) or in rock with less than half-a-diameter rock cover: 1.0% b) TBM works within rock with greater than half-a-diameter rock cover: 0.5% c) Non-TBM works, the corresponding values have been taken as 50% more than that of TBM works.
3	In the building damage assessment works, the following assumptions forms the basis of the assessment: a) all the basement/station box excavations will adopt top-down method of construction and retaining walls supported using high level props during construction; b) perimeter walls for the main station boxes will be constructed using diaphragm walling method; c) perimeter walls for the sub-excavations adjacent to the main station box will be constructed using secant pile wall method; d) portals, shafts and retained cuttings will be constructed using secant pile walls; e) no dewatering outside the boundaries of the site during construction.
4	In the assessment it has been assumed that the Airport and City tunnels will be formed using TBMs and all other tunnels/caverns using a non-TBM construction method. Although the airport ventilation and evacuation tunnels might be formed using TBMs, in this preliminary assessment, it has been conservatively assumed that they also will be formed using a non-TBM method.

No.	Assumption Description
5	The assessment works carried out in this report is based on the final cumulative ground movements due to the combined effects of the tunnelling and all the excavation works. The D&B Contractor will consider the actual sequence of construction in the Phase 2b/Phase 3 assessment to ensure that the intermediate stage of construction is not any more critical than the final condition.
6	The D&B Contractor will carry out the Phase 2b and Phase 3 building assessment works. It has been assumed that a) as part of Phase 2b assessment works, the D&B Contractor will review and refine the Phase 2a assessment work based on updated information; b) despite the Phase 2b assessment results, all the Protected/Prominent/Sensitive buildings or those buildings which fall into the conditions given in 2.11 of the Settlement Damage Assessment Methodology (See Appendix D) will be subject to Phase 3 assessment by the D&B Contractor; c) based on the Phase 3 assessment results, the D&B Contractor will take appropriate control or mitigation measures, if considered necessary, to limit the damage to an acceptable level.
7	Preliminary building surveys have been carried for the Representative buildings and used for the Phase 2a assessment. The general details of the Additional buildings (Table 5-4) have been obtained from publicly available maps. No survey has been carried out for these buildings. For the assessment, these buildings have been assumed to be supported on shallow foundations. An appropriate level of survey will be carried out to confirm the basis of the assessments at the next phase of works.
8	At the end of the refined Phase 2a assessment, except for buildings AB11 & AB13 (terraced residential blocks south of Griffith Park station), all buildings have fallen into Damage Category 2 or below. It is assumed that the Phase 3 assessment will bring the damage category level of buildings AB11 & AB13 to below Damage Category 2. Even if does not, it is assumed that post-construction repair work, together with implementation of an appropriate instrumentation and monitoring strategy would likely be required.
9	The D&B Contractor will adopt appropriate control measures to minimise the risk of damage to existing structures, utilities and assets, particularly during the excavation for the diaphragm wall construction, and will incorporate differing or enhanced techniques to minimise ground movements where risk is identified.

No.	Assumption Description
10	A preliminary impact assessment has been carried out as a part of this report on the existing bridges that could be potentially impacted by the settlement impact due to the Metrolink scheme based on the Phase 1 greenfield settlement contours. For this assessment, these bridges have been assumed to be simply supported on bearings and resting on shallow foundations. Further, it has been assumed that no mitigation measures will be required if the predicted total settlements and differential settlement gradients are less than 30mm and 1/500 respectively assuming that the bridges are in structurally in good condition. These assumptions and threshold limits will be confirmed/verified during the detailed design phase by carrying a detailed structural survey of these bridges and in consultation with the asset owners. The revised information shall then be used for the detailed damage assessment to be carried out by the D&B Contractor to determine any particular mitigation measures required.
11	The D&B Contractor will liaise with the owners of the Cross Guns Quay canal lock and the associated structures and carry out appropriate level of survey and detailed assessment to determine the necessary control/mitigation measures required to ensure the safe and continuous operation of the gates.
12	The D&B Contractor will liaise with Irish Railway, LUAS line operators, highway authorities, utility companies and with the Dublin Airport Authority to agree the allowable limits of total and differential ground movements in order to determine any mitigation/intervention requirements and the necessary instrumentation and monitoring works as part of the detailed design works. Irrespective of the assessment findings, it is likely that instrumentation and monitoring will be mandatory considering the nature of critical infrastructure.
13	There are new developments proposed to be constructed within the settlement impact zone of the MetroLink scheme. Some of these developments would likely be constructed before the commencement of tunnelling and station box/retaining cutting works associated with the MetroLink scheme. It is assumed that the detailed designers of these developments have been informed of the proposed MetroLink scheme and they will take account of the impact due to the MetroLink scheme in the design of these developments.

Appendix F. Building Damage Assessment Calculation Summary (XDisp Input/Output)

In this Appendix, the key inputs to the XDisp program and outputs from XDisp program are provided.

Key input parameters for the Xdisp program are as follows:

a) Overall ground conditions: these are obtained from the geological long sections (see Apendix A) and given in Table 5-1.
b) Volume loss adopted for TBM tunnelling works: Tabulated in Table 5-1.
c) For Non-TBM works, the volume loss values have been taken as 50% more than that of the TBM works.
d) Trough width parameters: Tabulated in Table 5-1.
e) Ground movements caused by the wall construction: based normalised curves given in CIRIA report 760 which is based on case history data.
f) Ground movements caused by the bulk excavation: based normalised curves given in CIRIA report 760 which is based on case history data.
g) Building information used: Tabulated in Table 5-2 for Representative building and in Table 5-4 for Additional building.
h) Building location: obtained from the OS map with the displacemnt line being taken at the worst case orientation through each building.

Key outputs from the XDisp program are given in Table F1 below.

The maximum tensile strain for each sub-building and the corresponding Damage Catogory are included in the Table.

JACOBS
IDOM

Table F1: Building Damage Assessment Results for 'Representative' and 'Additional' Buildings - Critical Segments within Each Building (Rev 1)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
B-132	Max Slope	1	0	11.245	Sagging	0.0012557	23.742	0.013413	-	5528.7	0 (Negligible)
	Max Settlement	1	0	11.245	Sagging	0.0012557	23.742	0.013413	-	5528.7	0 (Negligible)
	Max Tensile Strain	2	11.245	37.289	Hogging	0.0012557	14.41	0.054711	12469	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	11.245	37.289	Hogging	0.0012557	14.41	0.054711	12469	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	1	0	11.245	Sagging	0.0012557	23.742	0.013413	-	5528.7	0 (Negligible)
B-167	All vertical displacements are less than the limit sensitivity.										
B-240	Max Slope	1	0	18.26	Hogging	7.57E-04	6.9376	0.087196	11563	-	2 (Slight)
	Max Settlement	1	0	18.26	Hogging	7.57E-04	6.9376	0.087196	11563	-	2 (Slight)
	Max Tensile Strain	1	0	18.26	Hogging	7.57E-04	6.9376	0.087196	11563	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	18.26	Hogging	7.57E-04	6.9376	0.087196	11563	-	2 (Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-131	Max Slope	2	38.222	59.497	Sagging	0.0014705	25.516	0.028954	-	4486.6	0 (Negligible)
	Max Settlement	2	38.222	59.497	Sagging	0.0014705	25.516	0.028954	-	4486.6	0 (Negligible)
	Max Tensile Strain	1	15.379	38.222	Hogging	0.0014622	15.141	0.05012	10109	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	15.379	38.222	Hogging	0.0014622	15.141	0.05012	10109	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	38.222	59.497	Sagging	0.0014705	25.516	0.028954	-	4486.6	0 (Negligible)
B-166(b)	Max Slope	1	0	15.559	Hogging	0.0013381	14.841	0.046402	11284	-	0 (Negligible)
	Max Settlement	2	15.559	32.816	Sagging	0.0013381	24.453	0.022818	-	5012.1	0 (Negligible)
	Max Tensile Strain	1	0	15.559	Hogging	0.0013381	14.841	0.046402	11284	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	0	15.559	Hogging	0.0013381	14.841	0.046402	11284	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	2	15.559	32.816	Sagging	0.0013381	24.453	0.022818	-	5012.1	0 (Negligible)
B-165	Max Slope	1	0	17.661	Hogging	0.0014477	10.027	0.053536	7791	-	1 (Very Slight)
	Max Settlement	1	0	17.661	Hogging	0.0014477	10.027	0.053536	7791	-	1 (Very Slight)
	Max Tensile Strain	1	0	17.661	Hogging	0.0014477	10.027	0.053536	7791	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	0	17.661	Hogging	0.0014477	10.027	0.053536	7791	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-129	Max Slope	1	0	37.07	Hogging	3.76E-04	7.3198	0.041415	80743	-	0 (Negligible)
	Max Settlement	1	0	37.07	Hogging	3.76E-04	7.3198	0.041415	80743	-	0 (Negligible)
	Max Tensile Strain	1	0	37.07	Hogging	3.76E-04	7.3198	0.041415	80743	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	0	37.07	Hogging	3.76E-04	7.3198	0.041415	80743	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-127	Max Slope	1	46.551	68.732	Hogging	0.0016878	16.402	0.055648	7931.7	-	1 (Very Slight)
	Max Settlement	2	68.732	88.276	Sagging	0.0016878	27.116	0.033618	-	3529	0 (Negligible)
	Max Tensile Strain	1	46.551	68.732	Hogging	0.0016878	16.402	0.055648	7931.7	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	46.551	68.732	Hogging	0.0016878	16.402	0.055648	7931.7	-	1 (Very Slight)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Min Radius of Curvature (Sagging)	2	68.732	88.276	Sagging	0.0016878	27.116	0.033618	-	3529	0 (Negligible)
B-232	Max Slope	1	0	9.804	Sagging	0.0012029	10.742	0.046945	-	11886	0 (Negligible)
	Max Settlement	1	0	9.804	Sagging	0.0012029	10.742	0.046945	-	11886	0 (Negligible)
	Max Tensile Strain	1	0	9.804	Sagging	0.0012029	10.742	0.046945	-	11886	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-233	Max Slope	1	0	8.8932	Sagging	0.0012674	22.996	0.012059	-	5769	0 (Negligible)
	Max Settlement	1	0	8.8932	Sagging	0.0012674	22.996	0.012059	-	5769	0 (Negligible)
	Max Tensile Strain	1	0	8.8932	Sagging	0.0012674	22.996	0.012059	-	5769	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-126	Max Slope	1	0	18.647	Hogging	0.0017945	17.411	0.073505	7416.7	-	1 (Very Slight)
	Max Settlement	2	18.647	37.932	Sagging	0.0017945	28.648	0.016007	-	3269.7	0 (Negligible)
	Max Tensile Strain	1	0	18.647	Hogging	0.0017945	17.411	0.073505	7416.7	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	0	18.647	Hogging	0.0017945	17.411	0.073505	7416.7	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	18.647	37.932	Sagging	0.0017945	28.648	0.016007	-	3269.7	0 (Negligible)
B-125	Max Slope	1	0	2.535	Sagging	0.0016131	16.087	0.015752	-	15833	0 (Negligible)
	Max Settlement	2	2.535	22.549	Sagging	0.0016131	26.553	0.0139	-	3769.3	0 (Negligible)
	Max Tensile Strain	3	22.549	38.388	Hogging	0.001606	16.122	0.064206	8535.4	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	3	22.549	38.388	Hogging	0.001606	16.122	0.064206	8535.4	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	2.535	22.549	Sagging	0.0016131	26.553	0.0139	-	3769.3	0 (Negligible)
B-124	Max Slope	4	22.479	24.439	Sagging	0.0010839	29.605	0.075783	-	25610	2 (Slight)
	Max Settlement	1	0	11.707	Sagging	9.48E-04	49.668	0.035644	-	28252	0 (Negligible)
	Max Tensile Strain	6	26.701	59.887	Hogging	0.0010407	25.184	0.089774	5666.6	-	2 (Slight)
	Min Radius of Curvature (Hogging)	6	26.701	59.887	Hogging	0.0010407	25.184	0.089774	5666.6	-	2 (Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-145	Max Slope	1	0	13.729	Hogging	0.0010845	5.9403	0.037889	7046.7	-	0 (Negligible)
	Max Settlement	1	0	13.729	Hogging	0.0010845	5.9403	0.037889	7046.7	-	0 (Negligible)
	Max Tensile Strain	1	0	13.729	Hogging	0.0010845	5.9403	0.037889	7046.7	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	0	13.729	Hogging	0.0010845	5.9403	0.037889	7046.7	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-164	Max Slope	1	0	10.977	Sagging	6.14E-04	7.0285	0.019606	-	25363	0 (Negligible)
	Max Settlement	2	10.977	11.806	Sagging	6.14E-04	7.5365	3.64E-04	-	139370	0 (Negligible)
	Max Tensile Strain	1	0	10.977	Sagging	6.14E-04	7.0285	0.019606	-	25363	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-161	Max Slope	1	0	9.57	Sagging	3.49E-04	2.2048	0.017161	-	25706	0 (Negligible)
	Max Settlement	1	0	9.57	Sagging	3.49E-04	2.2048	0.017161	-	25706	0 (Negligible)
	Max Tensile Strain	1	0	9.57	Sagging	3.49E-04	2.2048	0.017161	-	25706	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-144	Max Slope	1	0	1.2457	Sagging	6.98E-04	11.343	6.16E-04	-	130810	0 (Negligible)
	Max Settlement	1	0	1.2457	Sagging	6.98E-04	11.343	6.16E-04	-	130810	0 (Negligible)
	Max Tensile Strain	2	1.2457	7.99	Sagging	6.98E-04	10.476	0.014354	-	33844	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-143	All vertical displacements are less than the limit sensitivity.										
B-142	Max Slope	1	0	2.7386	Sagging	0.0033773	33.722	0.012052	-	2411.7	0 (Negligible)
	Max Settlement	1	0	2.7386	Sagging	0.0033773	33.722	0.012052	-	2411.7	0 (Negligible)
	Max Tensile Strain	2	2.7386	11.727	Hogging	0.0033773	24.998	0.10701	2787.6	-	2 (Slight)
	Min Radius of Curvature (Hogging)	2	2.7386	11.727	Hogging	0.0033773	24.998	0.10701	2787.6	-	2 (Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-159	Max Slope	1	0	4.7122	Hogging	0.0042487	26.754	0.092327	2014.4	-	2 (Slight)
	Max Settlement	2	4.7122	14.512	Sagging	0.0042487	43.996	0.05983	-	889.47	1 (Very Slight)
	Max Tensile Strain	1	0	4.7122	Hogging	0.0042487	26.754	0.092327	2014.4	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	4.7122	Hogging	0.0042487	26.754	0.092327	2014.4	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	4.7122	14.512	Sagging	0.0042487	43.996	0.05983	-	889.47	1 (Very Slight)
B-244	Max Slope	1	0	11.113	Sagging	0.0033994	38.477	0.046715	-	1219.5	0 (Negligible)
	Max Settlement	1	0	11.113	Sagging	0.0033994	38.477	0.046715	-	1219.5	0 (Negligible)
	Max Tensile Strain	2	11.113	14.761	Sagging	0.0033994	23.37	0.062986	-	2982.7	1 (Very Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	11.113	Sagging	0.0033994	38.477	0.046715	-	1219.5	0 (Negligible)
B-158	Max Slope	1	0	9.4492	Sagging	0.0013883	17.682	0.016352	-	3359.5	0 (Negligible)
	Max Settlement	1	0	9.4492	Sagging	0.0013883	17.682	0.016352	-	3359.5	0 (Negligible)
	Max Tensile Strain	2	9.4492	20.94	Hogging	0.0013883	10.738	0.047925	7582.8	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	9.4492	20.94	Hogging	0.0013883	10.738	0.047925	7582.8	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	1	0	9.4492	Sagging	0.0013883	17.682	0.016352	-	3359.5	0 (Negligible)
B-123	Max Slope	1	0	5.6613	Sagging	0.0023347	30.511	0.015807	-	2563.1	0 (Negligible)
	Max Settlement	1	0	5.6613	Sagging	0.0023347	30.511	0.015807	-	2563.1	0 (Negligible)
	Max Tensile Strain	2	5.6613	21.2	Hogging	0.0023347	19.516	0.087713	4875.5	-	2 (Slight)
	Min Radius of Curvature (Hogging)	2	5.6613	21.2	Hogging	0.0023347	19.516	0.087713	4875.5	-	2 (Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-141	Max Slope	1	0	4.1147	Sagging	0.0011697	18.278	0.0045843	-	13169	0 (Negligible)
	Max Settlement	1	0	4.1147	Sagging	0.0011697	18.278	0.0045843	-	13169	0 (Negligible)
	Max Tensile Strain	2	4.1147	12.384	Sagging	0.0011697	13.678	0.035691	-	13567	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-122	Max Slope	1	0	15.608	Sagging	0.0013259	24.342	0.018889	-	5083.4	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Max Settlement	1	0	15.608	Sagging	0.0013259	24.342	0.018889	-	5083.4	0 (Negligible)
	Max Tensile Strain	2	15.608	34.97	Hogging	0.0013259	14.778	0.055248	11445	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	15.608	34.97	Hogging	0.0013259	14.778	0.055248	11445	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	1	0	15.608	Sagging	0.0013259	24.342	0.018889	-	5083.4	0 (Negligible)
B-139	Max Slope	1	0	13.774	Sagging	9.59E-04	21.791	0.016437	-	6803.5	0 (Negligible)
	Max Settlement	1	0	13.774	Sagging	9.59E-04	21.791	0.016437	-	6803.5	0 (Negligible)
	Max Tensile Strain	1	0	13.774	Sagging	9.59E-04	21.791	0.016437	-	6803.5	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	13.774	Sagging	9.59E-04	21.791	0.016437	-	6803.5	0 (Negligible)
B-140	Max Slope	1	0	11.681	Sagging	8.62E-04	22.523	0.01878	-	6185.4	0 (Negligible)
	Max Settlement	1	0	11.681	Sagging	8.62E-04	22.523	0.01878	-	6185.4	0 (Negligible)
	Max Tensile Strain	1	0	11.681	Sagging	8.62E-04	22.523	0.01878	-	6185.4	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	11.681	Sagging	8.62E-04	22.523	0.01878	-	6185.4	0 (Negligible)
B-120	Max Slope	1	0	7.8743	Sagging	0.0011145	20.843	0.0084064	-	7971.8	0 (Negligible)
	Max Settlement	1	0	7.8743	Sagging	0.0011145	20.843	0.0084064	-	7971.8	0 (Negligible)
	Max Tensile Strain	2	7.8743	13.55	Sagging	0.0011145	13.426	0.023814	-	16718	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-119	Max Slope	1	0	0.73039	Sagging	0.0017091	18.834	0.0013693	-	42077	0 (Negligible)
	Max Settlement	1	0	0.73039	Sagging	0.0017091	18.834	0.0013693	-	42077	0 (Negligible)
	Max Tensile Strain	2	0.73039	8.237	Sagging	0.0017091	17.588	0.044906	-	8039.1	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-121	Max Slope	1	0	12.264	Sagging	0.0016416	27.984	0.022969	-	3222.7	0 (Negligible)
	Max Settlement	1	0	12.264	Sagging	0.0016416	27.984	0.022969	-	3222.7	0 (Negligible)
	Max Tensile Strain	1	0	12.264	Sagging	0.0016416	27.984	0.022969	-	3222.7	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	12.264	Sagging	0.0016416	27.984	0.022969	-	3222.7	0 (Negligible)
B-157	Max Slope	1	0	18.369	Sagging	0.0015613	55.087	0.021175	-	3997.6	0 (Negligible)
	Max Settlement	1	0	18.369	Sagging	0.0015613	55.087	0.021175	-	3997.6	0 (Negligible)
	Max Tensile Strain	2	18.369	28.653	Hogging	0.0015613	44.711	0.022123	3436.8	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	18.369	28.653	Hogging	0.0015613	44.711	0.022123	3436.8	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	1	0	18.369	Sagging	0.0015613	55.087	0.021175	-	3997.6	0 (Negligible)
B-202	Max Slope	1	0	18.633	Sagging	8.71E-04	27.172	0.053189	-	7126.6	1 (Very Slight)
	Max Settlement	1	0	18.633	Sagging	8.71E-04	27.172	0.053189	-	7126.6	1 (Very Slight)
	Max Tensile Strain	2	18.633	18.937	Sagging	5.39E-04	14.412	0.053867	-	76477	1 (Very Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
B-117	Max Slope	1	0	4.8037	Sagging	0.0012283	50.488	0.0033971	-	1096.8	0 (Negligible)
	Max Settlement	1	0	4.8037	Sagging	0.0012283	50.488	0.0033971	-	1096.8	0 (Negligible)
	Max Tensile Strain	2	4.8037	10.92	Sagging	0.0012282	46.052	0.0099188	-	25723	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-118	Max Slope	1	0	16.843	Sagging	0.0014637	53.638	0.017877	-	11410	0 (Negligible)
	Max Settlement	1	0	16.843	Sagging	0.0014637	53.638	0.017877	-	11410	0 (Negligible)
	Max Tensile Strain	1	0	16.843	Sagging	0.0014637	53.638	0.017877	-	11410	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	16.843	Sagging	0.0014637	53.638	0.017877	-	11410	0 (Negligible)
B-116	Max Slope	1	0	14.62	Sagging	0.001025	21.525	0.011885	-	7480.4	0 (Negligible)
	Max Settlement	1	0	14.62	Sagging	0.001025	21.525	0.011885	-	7480.4	0 (Negligible)
	Max Tensile Strain	2	14.62	23.085	Sagging	0.001025	13.08	0.029103	-	17100	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	14.62	Sagging	0.001025	21.525	0.011885	-	7480.4	0 (Negligible)
B-115	Max Slope	1	0	9.837	Sagging	9.35E-04	20.448	0.011483	-	8353.3	0 (Negligible)
	Max Settlement	1	0	9.837	Sagging	9.35E-04	20.448	0.011483	-	8353.3	0 (Negligible)
	Max Tensile Strain	1	0	9.837	Sagging	9.35E-04	20.448	0.011483	-	8353.3	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-114	Max Slope	1	0	3.4044	Sagging	8.59E-04	12.005	0.01006	-	41884	0 (Negligible)
	Max Settlement	2	3.4044	31.539	Sagging	8.59E-04	19.84	0.0081562	-	9943.2	0 (Negligible)
	Max Tensile Strain	1	0	3.4044	Sagging	8.59E-04	12.005	0.01006	-	41884	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	2	3.4044	31.539	Sagging	8.59E-04	19.84	0.0081562	-	9943.2	0 (Negligible)
B-113	Max Slope	1	0	20.691	Sagging	8.54E-04	19.482	0.011234	-	9927.2	0 (Negligible)
	Max Settlement	1	0	20.691	Sagging	8.54E-04	19.482	0.011234	-	9927.2	0 (Negligible)
	Max Tensile Strain	2	20.691	40.696	Hogging	8.54E-04	11.786	0.035287	22024	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	20.691	40.696	Hogging	8.54E-04	11.786	0.035287	22024	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	1	0	20.691	Sagging	8.54E-04	19.482	0.011234	-	9927.2	0 (Negligible)
B-201	Max Slope	1	0	2.6909	Sagging	8.50E-04	11.909	0.0080107	-	51333	0 (Negligible)
	Max Settlement	2	2.6909	31.145	Sagging	8.50E-04	19.822	0.011474	-	10118	0 (Negligible)
	Max Tensile Strain	2	2.6909	31.145	Sagging	8.50E-04	19.822	0.011474	-	10118	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	2	2.6909	31.145	Sagging	8.50E-04	19.822	0.011474	-	10118	0 (Negligible)
B-112	Max Slope	1	0	4.9172	Sagging	8.35E-04	16.071	0.0028417	-	25257	0 (Negligible)
	Max Settlement	1	0	4.9172	Sagging	8.35E-04	16.071	0.0028417	-	25257	0 (Negligible)
	Max Tensile Strain	2	4.9172	37.262	Hogging	8.35E-04	12.13	0.033104	23856	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	4.9172	37.262	Hogging	8.35E-04	12.13	0.033104	23856	-	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-110	Max Slope	1	0	13.147	Sagging	7.95E-04	21.013	0.016087	-	7586.6	0 (Negligible)
	Max Settlement	1	0	13.147	Sagging	7.95E-04	21.013	0.016087	-	7586.6	0 (Negligible)
	Max Tensile Strain	1	0	13.147	Sagging	7.95E-04	21.013	0.016087	-	7586.6	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	13.147	Sagging	7.95E-04	21.013	0.016087	-	7586.6	0 (Negligible)
B-111	Max Slope	1	0	1.297	Sagging	0.0010379	14.377	0.0011425	-	65917	0 (Negligible)
	Max Settlement	1	0	1.297	Sagging	0.0010379	14.377	0.0011425	-	65917	0 (Negligible)
	Max Tensile Strain	2	1.297	25.831	Hogging	0.0010379	13.036	0.046775	16461	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	1.297	25.831	Hogging	0.0010379	13.036	0.046775	16461	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-109	Max Slope	1	0	11.604	Sagging	0.0010093	21.052	0.010412	-	7726.9	0 (Negligible)
	Max Settlement	1	0	11.604	Sagging	0.0010093	21.052	0.010412	-	7726.9	0 (Negligible)
	Max Tensile Strain	2	11.604	21.029	Sagging	0.0010093	12.823	0.031983	-	17071	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	11.604	Sagging	0.0010093	21.052	0.010412	-	7726.9	0 (Negligible)
B-108	Max Slope	1	0	13.94	Sagging	9.10E-04	21.137	0.017486	-	7290.9	0 (Negligible)
	Max Settlement	1	0	13.94	Sagging	9.10E-04	21.137	0.017486	-	7290.9	0 (Negligible)
	Max Tensile Strain	1	0	13.94	Sagging	9.10E-04	21.137	0.017486	-	7290.9	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	13.94	Sagging	9.10E-04	21.137	0.017486	-	7290.9	0 (Negligible)
B-107	Max Slope	1	0	10.782	Sagging	9.24E-04	20.186	0.0093128	-	8681.9	0 (Negligible)
	Max Settlement	1	0	10.782	Sagging	9.24E-04	20.186	0.0093128	-	8681.9	0 (Negligible)
	Max Tensile Strain	2	10.782	16.124	Sagging	9.24E-04	12.648	0.013034	-	25197	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-106	Max Slope	1	0	11.51	Sagging	0.0011605	22.256	0.014573	-	5772.3	0 (Negligible)
	Max Settlement	1	0	11.51	Sagging	0.0011605	22.256	0.014573	-	5772.3	0 (Negligible)
	Max Tensile Strain	1	0	11.51	Sagging	0.0011605	22.256	0.014573	-	5772.3	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	11.51	Sagging	0.0011605	22.256	0.014573	-	5772.3	0 (Negligible)
B-105	Max Slope	1	0	14.653	Sagging	0.0016761	27.488	0.01954	-	3628.5	0 (Negligible)
	Max Settlement	1	0	14.653	Sagging	0.0016761	27.488	0.01954	-	3628.5	0 (Negligible)
	Max Tensile Strain	2	14.653	17.773	Sagging	0.0016761	16.652	0.019785	-	12116	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	14.653	Sagging	0.0016761	27.488	0.01954	-	3628.5	0 (Negligible)
B-235	Max Slope	1	0	3.1905	Sagging	0.0013592	19.247	0.0029528	-	13540	0 (Negligible)
	Max Settlement	1	0	3.1905	Sagging	0.0013592	19.247	0.0029528	-	13540	0 (Negligible)
	Max Tensile Strain	2	3.1905	16.316	Hogging	0.0013592	15.037	0.052423	11041	-	1 (Very Slight)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Min Radius of Curvature (Hogging)	2	3.1905	16.316	Hogging	0.0013592	15.037	0.052423	11041	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-103	Max Slope	2	3.1173	18.774	Sagging	0.0025006	42.948	0.039035	-	1889.8	0 (Negligible)
	Max Settlement	2	3.1173	18.774	Sagging	0.0025006	42.948	0.039035	-	1889.8	0 (Negligible)
	Max Tensile Strain	3	18.774	31.223	Hogging	0.0025006	30.372	0.06192	4411.4	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	3	18.774	31.223	Hogging	0.0025006	30.372	0.06192	4411.4	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	3.1173	18.774	Sagging	0.0025006	42.948	0.039035	-	1889.8	0 (Negligible)
B-102	All vertical displacements are less than the limit sensitivity.										
B-236	Max Slope	1	0	11.381	Sagging	4.27E-04	25.106	0.060064	-	82404	1 (Very Slight)
	Max Settlement	3	11.864	17.454	Sagging	3.87E-04	27.053	0.058692	-	26167	1 (Very Slight)
	Max Tensile Strain	1	0	11.381	Sagging	4.27E-04	25.106	0.060064	-	82404	1 (Very Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-237	Max Slope	1	0	11.636	Sagging	7.56E-04	49.1	0.11691	-	14161	2 (Slight)
	Max Settlement	1	0	11.636	Sagging	7.56E-04	49.1	0.11691	-	14161	2 (Slight)
	Max Tensile Strain	1	0	11.636	Sagging	7.56E-04	49.1	0.11691	-	14161	2 (Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-101	Max Slope	1	0	1.5202	Sagging	0.0030929	23.751	0.012956	-	9497	0 (Negligible)
	Max Settlement	2	1.5202	17.151	Sagging	0.0030929	39.411	0.068754	-	1550	1 (Very Slight)
	Max Tensile Strain	2	1.5202	17.151	Sagging	0.0030929	39.411	0.068754	-	1550	1 (Very Slight)
	Min Radius of Curvature (Hogging)	3	17.151	36.361	Hogging	0.0030467	23.98	0.060295	3527.8	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	1.5202	17.151	Sagging	0.0030929	39.411	0.068754	-	1550	1 (Very Slight)
B-100	Max Slope	1	0	12.354	Sagging	0.0013591	35.131	0.02235	-	804.96	0 (Negligible)
	Max Settlement	1	0	12.354	Sagging	0.0013591	35.131	0.02235	-	804.96	0 (Negligible)
	Max Tensile Strain	1	0	12.354	Sagging	0.0013591	35.131	0.02235	-	804.96	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	12.354	Sagging	0.0013591	35.131	0.02235	-	804.96	0 (Negligible)
B-99	Max Slope	1	0	2.5283	Sagging	0.003749	33.764	0.010048	-	2228	0 (Negligible)
	Max Settlement	1	0	2.5283	Sagging	0.003749	33.764	0.010048	-	2228	0 (Negligible)
	Max Tensile Strain	2	2.5283	18.757	Hogging	0.003749	24.78	0.095726	2401.4	-	2 (Slight)
	Min Radius of Curvature (Hogging)	2	2.5283	18.757	Hogging	0.003749	24.78	0.095726	2401.4	-	2 (Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-98	Max Slope	2	9.8095	24.469	Sagging	0.0029008	35.581	0.0462	-	1556.9	0 (Negligible)
	Max Settlement	2	9.8095	24.469	Sagging	0.0029008	35.581	0.0462	-	1556.9	0 (Negligible)
	Max Tensile Strain	1	0	9.8095	Hogging	0.0028892	21.621	0.068845	3527.1	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	0	9.8095	Hogging	0.0028892	21.621	0.068845	3527.1	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	9.8095	24.469	Sagging	0.0029008	35.581	0.0462	-	1556.9	0 (Negligible)
B-96	Max Slope	1	9.3056	23.263	Hogging	0.0022299	10.95	0.053983	3477.6	-	1 (Very Slight)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Max Settlement	1	9.3056	23.263	Hogging	0.0022299	10.95	0.053983	3477.6	-	1 (Very Slight)
	Max Tensile Strain	1	9.3056	23.263	Hogging	0.0022299	10.95	0.053983	3477.6	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	9.3056	23.263	Hogging	0.0022299	10.95	0.053983	3477.6	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-95	Max Slope	1	0	15.508	Sagging	0.0024054	32.734	0.043593	-	2109.2	0 (Negligible)
	Max Settlement	1	0	15.508	Sagging	0.0024054	32.734	0.043593	-	2109.2	0 (Negligible)
	Max Tensile Strain	2	15.508	26.363	Hogging	0.0024054	19.799	0.053803	4655.7	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	15.508	26.363	Hogging	0.0024054	19.799	0.053803	4655.7	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	1	0	15.508	Sagging	0.0024054	32.734	0.043593	-	2109.2	0 (Negligible)
B-94	Max Slope	1	0	8.9111	Sagging	7.67E-04	2.6722	0.025813	-	5564.1	0 (Negligible)
	Max Settlement	1	0	8.9111	Sagging	7.67E-04	2.6722	0.025813	-	5564.1	0 (Negligible)
	Max Tensile Strain	1	0	8.9111	Sagging	7.67E-04	2.6722	0.025813	-	5564.1	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-93	Max Slope	1	0	4.2882	Sagging	0.0027396	31.413	0.01225	-	2390.2	0 (Negligible)
	Max Settlement	1	0	4.2882	Sagging	0.0027396	31.413	0.01225	-	2390.2	0 (Negligible)
	Max Tensile Strain	2	4.2882	22.77	Hogging	0.0027396	21	0.069905	3809.2	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	4.2882	22.77	Hogging	0.0027396	21	0.069905	3809.2	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-92	Max Slope	1	0	14.783	Hogging	0.0020932	10.956	0.051445	3957.8	-	1 (Very Slight)
	Max Settlement	1	0	14.783	Hogging	0.0020932	10.956	0.051445	3957.8	-	1 (Very Slight)
	Max Tensile Strain	1	0	14.783	Hogging	0.0020932	10.956	0.051445	3957.8	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	0	14.783	Hogging	0.0020932	10.956	0.051445	3957.8	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-91	Max Slope	1	0	5.0798	Sagging	0.0026148	31.785	0.014274	-	2261	0 (Negligible)
	Max Settlement	1	0	5.0798	Sagging	0.0026148	31.785	0.014274	-	2261	0 (Negligible)
	Max Tensile Strain	2	5.0798	22.3	Hogging	0.0026148	20.519	0.061682	4085.2	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	5.0798	22.3	Hogging	0.0026148	20.519	0.061682	4085.2	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-90	Max Slope	1	0	10.75	Hogging	0.001009	4.0174	0.030795	5065.8	-	0 (Negligible)
	Max Settlement	1	0	10.75	Hogging	0.001009	4.0174	0.030795	5065.8	-	0 (Negligible)
	Max Tensile Strain	1	0	10.75	Hogging	0.001009	4.0174	0.030795	5065.8	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	0	10.75	Hogging	0.001009	4.0174	0.030795	5065.8	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-89	Max Slope	1	0	2.3904	Sagging	0.0020448	22.894	0.0036743	-	9154.4	0 (Negligible)
	Max Settlement	1	0	2.3904	Sagging	0.0020448	22.894	0.0036743	-	9154.4	0 (Negligible)
	Max Tensile Strain	2	2.3904	23.418	Hogging	0.0020448	18.125	0.056554	5917.5	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	2.3904	23.418	Hogging	0.0020448	18.125	0.056554	5917.5	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
B-88	Max Slope	1	0	16.553	Hogging	0.0015965	9.518	0.042427	5942.2	-	0 (Negligible)
	Max Settlement	1	0	16.553	Hogging	0.0015965	9.518	0.042427	5942.2	-	0 (Negligible)
	Max Tensile Strain	1	0	16.553	Hogging	0.0015965	9.518	0.042427	5942.2	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	0	16.553	Hogging	0.0015965	9.518	0.042427	5942.2	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-87	Max Slope	1	0	3.8105	Sagging	1.68E-04	0.49218	0.0090418	-	18278	0 (Negligible)
	Max Settlement	1	0	3.8105	Sagging	1.68E-04	0.49218	0.0090418	-	18278	0 (Negligible)
	Max Tensile Strain	1	0	3.8105	Sagging	1.68E-04	0.49218	0.0090418	-	18278	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-80	Max Slope	1	0	8.2694	Sagging	0.0024984	33.274	0.022086	-	1927.1	0 (Negligible)
	Max Settlement	1	0	8.2694	Sagging	0.0024984	33.274	0.022086	-	1927.1	0 (Negligible)
	Max Tensile Strain	2	8.2694	27.677	Hogging	0.0024984	20.265	0.084012	4422.8	-	2 (Slight)
	Min Radius of Curvature (Hogging)	2	8.2694	27.677	Hogging	0.0024984	20.265	0.084012	4422.8	-	2 (Slight)
	Min Radius of Curvature (Sagging)	1	0	8.2694	Sagging	0.0024984	33.274	0.022086	-	1927.1	0 (Negligible)
B-82	Max Slope	1	0	7.133	Hogging	0.003649	24.466	0.071811	2510.3	-	1 (Very Slight)
	Max Settlement	2	7.133	20.676	Sagging	0.003649	40.473	0.070925	-	1132.3	1 (Very Slight)
	Max Tensile Strain	3	20.676	37.32	Hogging	0.0036112	24.581	0.089184	2575.4	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	7.133	Hogging	0.003649	24.466	0.071811	2510.3	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	7.133	20.676	Sagging	0.003649	40.473	0.070925	-	1132.3	1 (Very Slight)
B-81	Max Slope	1	0	7.8041	Hogging	0.0037454	24.54	0.07716	2395.4	-	2 (Slight)
	Max Settlement	2	7.8041	20.933	Sagging	0.0037454	40.503	0.080302	-	1063.2	2 (Slight)
	Max Tensile Strain	3	20.933	37.089	Hogging	0.0037415	24.554	0.084122	2399.9	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	7.8041	Hogging	0.0037454	24.54	0.07716	2395.4	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	7.8041	20.933	Sagging	0.0037454	40.503	0.080302	-	1063.2	2 (Slight)
B-79	Max Slope	1	0	3.581	Sagging	0.0035101	35.115	0.014308	-	1865	0 (Negligible)
	Max Settlement	1	0	3.581	Sagging	0.0035101	35.115	0.014308	-	1865	0 (Negligible)
	Max Tensile Strain	2	3.581	19.929	Hogging	0.0035101	23.791	0.079638	2645.8	-	2 (Slight)
	Min Radius of Curvature (Hogging)	2	3.581	19.929	Hogging	0.0035101	23.791	0.079638	2645.8	-	2 (Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-77	Max Slope	2	8.3653	20.265	Sagging	0.0045583	44.774	0.10486	-	792.31	2 (Slight)
	Max Settlement	2	8.3653	20.265	Sagging	0.0045583	44.774	0.10486	-	792.31	2 (Slight)
	Max Tensile Strain	2	8.3653	20.265	Sagging	0.0045583	44.774	0.10486	-	792.31	2 (Slight)
	Min Radius of Curvature (Hogging)	3	20.265	34.643	Hogging	0.0045583	27.186	0.097028	1787.3	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	8.3653	20.265	Sagging	0.0045583	44.774	0.10486	-	792.31	2 (Slight)
B-76	Max Slope	2	14.583	25.741	Sagging	0.0050605	46.49	0.12019	-	669.93	2 (Slight)
	Max Settlement	2	14.583	25.741	Sagging	0.0050605	46.49	0.12019	-	669.93	2 (Slight)
	Max Tensile Strain	2	14.583	25.741	Sagging	0.0050605	46.49	0.12019	-	669.93	2 (Slight)
	Min Radius of Curvature (Hogging)	1	1.2187	14.583	Hogging	0.0050532	28.117	0.10857	1513.8	-	2 (Slight)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Min Radius of Curvature (Sagging)	2	14.583	25.741	Sagging	0.0050605	46.49	0.12019	-	669.93	2 (Slight)
B-75	Max Slope	1	1.219	14.35	Hogging	0.0036027	20.348	0.077565	2167.4	-	2 (Slight)
	Max Settlement	2	14.35	25.726	Sagging	0.0036027	33.683	0.083414	-	960.93	2 (Slight)
	Max Tensile Strain	2	14.35	25.726	Sagging	0.0036027	33.683	0.083414	-	960.93	2 (Slight)
	Min Radius of Curvature (Hogging)	3	25.726	39.007	Hogging	0.0035993	20.356	0.077367	2163.5	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	14.35	25.726	Sagging	0.0036027	33.683	0.083414	-	960.93	2 (Slight)
B-200	Max Slope	2	12.836	25.42	Sagging	0.0040582	42.114	0.092415	-	939.08	2 (Slight)
	Max Settlement	2	12.836	25.42	Sagging	0.0040582	42.114	0.092415	-	939.08	2 (Slight)
	Max Tensile Strain	2	12.836	25.42	Sagging	0.0040582	42.114	0.092415	-	939.08	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	12.836	Hogging	0.0040576	25.559	0.089327	2116.9	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	12.836	25.42	Sagging	0.0040582	42.114	0.092415	-	939.08	2 (Slight)
B-198	Max Slope	1	0	11.737	Hogging	0.0041765	26.026	0.092251	2033.6	-	2 (Slight)
	Max Settlement	2	11.737	24.184	Sagging	0.0041765	42.881	0.093134	-	902.24	2 (Slight)
	Max Tensile Strain	2	11.737	24.184	Sagging	0.0041765	42.881	0.093134	-	902.24	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	11.737	Hogging	0.0041765	26.026	0.092251	2033.6	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	11.737	24.184	Sagging	0.0041765	42.881	0.093134	-	902.24	2 (Slight)
B-199	Max Slope	1	0	12.927	Hogging	0.0041766	25.93	0.091408	2027.6	-	2 (Slight)
	Max Settlement	2	12.927	25.33	Sagging	0.0041766	42.726	0.093282	-	899.3	2 (Slight)
	Max Tensile Strain	2	12.927	25.33	Sagging	0.0041766	42.726	0.093282	-	899.3	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	12.927	Hogging	0.0041766	25.93	0.091408	2027.6	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	12.927	25.33	Sagging	0.0041766	42.726	0.093282	-	899.3	2 (Slight)
B-67	Max Slope	1	0	2.4791	Sagging	0.0020687	17.916	0.021278	-	11220	0 (Negligible)
	Max Settlement	2	2.4791	20.052	Sagging	0.0020687	29.678	0.043279	-	2606.7	0 (Negligible)
	Max Tensile Strain	3	20.052	40.106	Hogging	0.0020391	17.977	0.053861	5934.1	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	3	20.052	40.106	Hogging	0.0020391	17.977	0.053861	5934.1	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	2.4791	20.052	Sagging	0.0020687	29.678	0.043279	-	2606.7	0 (Negligible)
B-65	Max Slope	1	0	16.738	Hogging	7.73E-04	5.428	0.025314	14294	-	0 (Negligible)
	Max Settlement	1	0	16.738	Hogging	7.73E-04	5.428	0.025314	14294	-	0 (Negligible)
	Max Tensile Strain	1	0	16.738	Hogging	7.73E-04	5.428	0.025314	14294	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	0	16.738	Hogging	7.73E-04	5.428	0.025314	14294	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-192	Max Slope	1	0	9.0036	Sagging	0.0040802	42.362	0.069078	-	922.82	1 (Very Slight)
	Max Settlement	1	0	9.0036	Sagging	0.0040802	42.362	0.069078	-	922.82	1 (Very Slight)
	Max Tensile Strain	2	9.0036	25.466	Hogging	0.0040802	25.849	0.084158	2108.6	-	2 (Slight)
	Min Radius of Curvature (Hogging)	2	9.0036	25.466	Hogging	0.0040802	25.849	0.084158	2108.6	-	2 (Slight)
	Min Radius of Curvature (Sagging)	1	0	9.0036	Sagging	0.0040802	42.362	0.069078	-	922.82	1 (Very Slight)
B-191	Max Slope	1	0	14.316	Sagging	0.0031489	37.672	0.068756	-	1404.8	1 (Very Slight)
	Max Settlement	1	0	14.316	Sagging	0.0031489	37.672	0.068756	-	1404.8	1 (Very Slight)
	Max Tensile Strain	1	0	14.316	Sagging	0.0031489	37.672	0.068756	-	1404.8	1 (Very Slight)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	14.316	Sagging	0.0031489	37.672	0.068756	-	1404.8	1 (Very Slight)
B-190	Max Slope	1	0	11.302	Sagging	0.0032467	37.697	0.059156	-	1313.6	1 (Very Slight)
	Max Settlement	1	0	11.302	Sagging	0.0032467	37.697	0.059156	-	1313.6	1 (Very Slight)
	Max Tensile Strain	2	11.302	28.239	Hogging	0.0032466	22.859	0.074335	2958.8	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	11.302	28.239	Hogging	0.0032466	22.859	0.074335	2958.8	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	1	0	11.302	Sagging	0.0032467	37.697	0.059156	-	1313.6	1 (Very Slight)
B-241	Max Slope	1	0	3.3418	Sagging	0.0041987	26.007	0.054914	-	2194.6	1 (Very Slight)
	Max Settlement	2	3.3418	15.739	Sagging	0.0041987	42.882	0.097797	-	895.29	2 (Slight)
	Max Tensile Strain	2	3.3418	15.739	Sagging	0.0041987	42.882	0.097797	-	895.29	2 (Slight)
	Min Radius of Curvature (Hogging)	3	15.739	28.623	Hogging	0.0041863	26.046	0.0922	2025.1	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	3.3418	15.739	Sagging	0.0041987	42.882	0.097797	-	895.29	2 (Slight)
B-179	Max Slope	1	11.563	26.325	Hogging	0.004604	27.298	0.097389	1767.6	-	2 (Slight)
	Max Settlement	2	26.325	38.232	Sagging	0.004604	45.093	0.10247	-	786.68	2 (Slight)
	Max Tensile Strain	2	26.325	38.232	Sagging	0.004604	45.093	0.10247	-	786.68	2 (Slight)
	Min Radius of Curvature (Hogging)	1	11.563	26.325	Hogging	0.004604	27.298	0.097389	1767.6	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	26.325	38.232	Sagging	0.004604	45.093	0.10247	-	786.68	2 (Slight)
B-172	Max Slope	1	11.711	26.37	Hogging	0.0043104	26.103	0.095496	1919.3	-	2 (Slight)
	Max Settlement	2	26.37	34.444	Sagging	0.0043104	43.149	0.063597	-	864.64	1 (Very Slight)
	Max Tensile Strain	1	11.711	26.37	Hogging	0.0043104	26.103	0.095496	1919.3	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	11.711	26.37	Hogging	0.0043104	26.103	0.095496	1919.3	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	26.37	34.444	Sagging	0.0043104	43.149	0.063597	-	864.64	1 (Very Slight)
B-174	Max Slope	1	0	10.71	Sagging	0.0032863	38.272	0.046568	-	1376.4	0 (Negligible)
	Max Settlement	1	0	10.71	Sagging	0.0032863	38.272	0.046568	-	1376.4	0 (Negligible)
	Max Tensile Strain	2	10.71	20.686	Hogging	0.0032863	22.861	0.080436	2869.4	-	2 (Slight)
	Min Radius of Curvature (Hogging)	2	10.71	20.686	Hogging	0.0032863	22.861	0.080436	2869.4	-	2 (Slight)
	Min Radius of Curvature (Sagging)	1	0	10.71	Sagging	0.0032863	38.272	0.046568	-	1376.4	0 (Negligible)
B-175	Max Slope	1	0	11.191	Hogging	0.0046549	27.175	0.10346	1705.6	-	2 (Slight)
	Max Settlement	2	11.191	18.456	Sagging	0.0046549	45.062	0.062084	-	784.52	1 (Very Slight)
	Max Tensile Strain	1	0	11.191	Hogging	0.0046549	27.175	0.10346	1705.6	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	11.191	Hogging	0.0046549	27.175	0.10346	1705.6	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	11.191	18.456	Sagging	0.0046549	45.062	0.062084	-	784.52	1 (Very Slight)
B-59	Max Slope	1	0	12.732	Hogging	0.0044683	20.489	0.094141	1617.3	-	2 (Slight)
	Max Settlement	1	0	12.732	Hogging	0.0044683	20.489	0.094141	1617.3	-	2 (Slight)
	Max Tensile Strain	1	0	12.732	Hogging	0.0044683	20.489	0.094141	1617.3	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	12.732	Hogging	0.0044683	20.489	0.094141	1617.3	-	2 (Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-57	Max Slope	1	0	2.9424	Sagging	0.0017042	15.857	0.014401	-	11115	0 (Negligible)
	Max Settlement	2	2.9424	20.948	Sagging	0.0017042	25.997	0.030985	-	3241.4	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Max Tensile Strain	2	2.9424	20.948	Sagging	0.0017042	25.997	0.030985	-	3241.4	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	2	2.9424	20.948	Sagging	0.0017042	25.997	0.030985	-	3241.4	0 (Negligible)
B-56	Max Slope	1	0	15.097	Sagging	0.0011682	26.878	0.027344	-	7448.8	0 (Negligible)
	Max Settlement	1	0	15.097	Sagging	0.0011682	26.878	0.027344	-	7448.8	0 (Negligible)
	Max Tensile Strain	4	18.92	36.582	Hogging	0.0011134	16.8	0.047492	11471	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	4	18.92	36.582	Hogging	0.0011134	16.8	0.047492	11471	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	1	0	15.097	Sagging	0.0011682	26.878	0.027344	-	7448.8	0 (Negligible)
B-54	All vertical displacements are less than the limit sensitivity.										
B-51	Max Slope	2	8.4136	24.578	Sagging	0.0012299	16.363	0.02806	-	3996.9	0 (Negligible)
	Max Settlement	2	8.4136	24.578	Sagging	0.0012299	16.363	0.02806	-	3996.9	0 (Negligible)
	Max Tensile Strain	1	0	8.4136	Sagging	0.0012285	9.9202	0.031245	-	8996.3	0 (Negligible)
	Min Radius of Curvature (Hogging)	3	24.578	42.068	Hogging	0.0012299	9.9153	0.030907	8976.2	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	2	8.4136	24.578	Sagging	0.0012299	16.363	0.02806	-	3996.9	0 (Negligible)
B-50	Max Slope	1	0	8.5273	Sagging	0.0014318	17.811	0.018917	-	3185.3	0 (Negligible)
	Max Settlement	1	0	8.5273	Sagging	0.0014318	17.811	0.018917	-	3185.3	0 (Negligible)
	Max Tensile Strain	2	8.5273	21.982	Hogging	0.0014318	10.815	0.03732	7181.5	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	8.5273	21.982	Hogging	0.0014318	10.815	0.03732	7181.5	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	1	0	8.5273	Sagging	0.0014318	17.811	0.018917	-	3185.3	0 (Negligible)
B-49	Max Slope	1	0	9.8795	Sagging	0.0010282	15.28	0.012599	-	5287.9	0 (Negligible)
	Max Settlement	1	0	9.8795	Sagging	0.0010282	15.28	0.012599	-	5287.9	0 (Negligible)
	Max Tensile Strain	2	9.8795	19.167	Sagging	0.0010282	9.3044	0.028005	-	11934	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	9.8795	Sagging	0.0010282	15.28	0.012599	-	5287.9	0 (Negligible)
B-48	Max Slope	2	10.975	23.952	Sagging	0.0018681	22.166	0.034766	-	2266.7	0 (Negligible)
	Max Settlement	2	10.975	23.952	Sagging	0.0018681	22.166	0.034766	-	2266.7	0 (Negligible)
	Max Tensile Strain	1	0	10.975	Hogging	0.001779	14.038	0.040183	6094	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	0	10.975	Hogging	0.001779	14.038	0.040183	6094	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	2	10.975	23.952	Sagging	0.0018681	22.166	0.034766	-	2266.7	0 (Negligible)
B-46	Max Slope	1	0	18.909	Hogging	0.0031928	18.159	0.06615	2789.4	-	1 (Very Slight)
	Max Settlement	1	0	18.909	Hogging	0.0031928	18.159	0.06615	2789.4	-	1 (Very Slight)
	Max Tensile Strain	1	0	18.909	Hogging	0.0031928	18.159	0.06615	2789.4	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	0	18.909	Hogging	0.0031928	18.159	0.06615	2789.4	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-44	All vertical displacements are less than the limit sensitivity.										
B-42	Max Slope	1	0	9.9499	Sagging	0.0031373	39.613	0.038177	-	1556.3	0 (Negligible)
	Max Settlement	1	0	9.9499	Sagging	0.0031373	39.613	0.038177	-	1556.3	0 (Negligible)
	Max Tensile Strain	2	9.9499	28.415	Hogging	0.0031373	23.958	0.087077	3312.1	-	2 (Slight)
	Min Radius of Curvature (Hogging)	2	9.9499	28.415	Hogging	0.0031373	23.958	0.087077	3312.1	-	2 (Slight)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Min Radius of Curvature (Sagging)	1	0	9.9499	Sagging	0.0031373	39.613	0.038177	-	1556.3	0 (Negligible)
B-41	Max Slope	1	0	10.038	Hogging	0.0033354	23.197	0.07584	2838.8	-	2 (Slight)
	Max Settlement	2	10.038	23.461	Sagging	0.0033354	38.249	0.064292	-	1267.4	1 (Very Slight)
	Max Tensile Strain	1	0	10.038	Hogging	0.0033354	23.197	0.07584	2838.8	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	10.038	Hogging	0.0033354	23.197	0.07584	2838.8	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	10.038	23.461	Sagging	0.0033354	38.249	0.064292	-	1267.4	1 (Very Slight)
B-40	Max Slope	1	0	3.6852	Sagging	1.92E-04	0.545	0.0095036	-	15840	0 (Negligible)
	Max Settlement	1	0	3.6852	Sagging	1.92E-04	0.545	0.0095036	-	15840	0 (Negligible)
	Max Tensile Strain	1	0	3.6852	Sagging	1.92E-04	0.545	0.0095036	-	15840	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-39	Max Slope	1	17.054	34.681	Hogging	0.0031461	22.717	0.10343	3130.1	-	2 (Slight)
	Max Settlement	2	34.681	36.285	Sagging	0.0031461	27.678	0.0044271	-	5820.7	0 (Negligible)
	Max Tensile Strain	1	17.054	34.681	Hogging	0.0031461	22.717	0.10343	3130.1	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	17.054	34.681	Hogging	0.0031461	22.717	0.10343	3130.1	-	2 (Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-37	All vertical displacements are less than the limit sensitivity.										
B-38	Max Slope	1	17.141	38.244	Hogging	8.41E-04	8.3787	0.027185	16132	-	0 (Negligible)
	Max Settlement	2	38.244	42.853	Sagging	8.41E-04	11.961	0.0035576	-	12575	0 (Negligible)
	Max Tensile Strain	1	17.141	38.244	Hogging	8.41E-04	8.3787	0.027185	16132	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	17.141	38.244	Hogging	8.41E-04	8.3787	0.027185	16132	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-36	All vertical displacements are less than the limit sensitivity.										
B-35	Max Slope	1	0	6.3618	Sagging	1.50E-04	0.65492	0.0092381	-	32768	0 (Negligible)
	Max Settlement	1	0	6.3618	Sagging	1.50E-04	0.65492	0.0092381	-	32768	0 (Negligible)
	Max Tensile Strain	1	0	6.3618	Sagging	1.50E-04	0.65492	0.0092381	-	32768	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-34	All vertical displacements are less than the limit sensitivity.										
B-32	Max Slope	1	31.711	39.149	Sagging	1.60E-04	0.7282	0.0091942	-	33392	0 (Negligible)
	Max Settlement	1	31.711	39.149	Sagging	1.60E-04	0.7282	0.0091942	-	33392	0 (Negligible)
	Max Tensile Strain	1	31.711	39.149	Sagging	1.60E-04	0.7282	0.0091942	-	33392	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-31	All vertical displacements are less than the limit sensitivity.										
B-30	All vertical displacements are less than the limit sensitivity.										
B-21	All vertical displacements are less than the limit sensitivity.										
B-22	Max Slope	1	0	8.3529	Sagging	5.10E-04	10.725	0.0027666	-	20793	0 (Negligible)
	Max Settlement	1	0	8.3529	Sagging	5.10E-04	10.725	0.0027666	-	20793	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Max Tensile Strain	2	8.3529	29.251	Hogging	5.10E-04	7.0432	0.014391	37003	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	8.3529	29.251	Hogging	5.10E-04	7.0432	0.014391	37003	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-25	Max Slope	1	0	6.8767	Sagging	1.08E-04	0.51885	0.0062871	-	52031	0 (Negligible)
	Max Settlement	1	0	6.8767	Sagging	1.08E-04	0.51885	0.0062871	-	52031	0 (Negligible)
	Max Tensile Strain	1	0	6.8767	Sagging	1.08E-04	0.51885	0.0062871	-	52031	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-24	Max Slope	1	0	5.0404	Sagging	5.92E-04	9.7859	0.0022195	-	22658	0 (Negligible)
	Max Settlement	1	0	5.0404	Sagging	5.92E-04	9.7859	0.0022195	-	22658	0 (Negligible)
	Max Tensile Strain	2	5.0404	29.475	Hogging	5.92E-04	6.9953	0.018818	27156	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	5.0404	29.475	Hogging	5.92E-04	6.9953	0.018818	27156	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-27	All vertical displacements are less than the limit sensitivity.										
B-16	Max Slope	2	41.8	61.795	Sagging	8.08E-04	13.309	0.016599	-	7522.1	0 (Negligible)
	Max Settlement	2	41.8	61.795	Sagging	8.08E-04	13.309	0.016599	-	7522.1	0 (Negligible)
	Max Tensile Strain	1	20.882	41.8	Hogging	8.07E-04	8.069	0.022307	16892	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	20.882	41.8	Hogging	8.07E-04	8.069	0.022307	16892	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	2	41.8	61.795	Sagging	8.08E-04	13.309	0.016599	-	7522.1	0 (Negligible)
B-17	Max Slope	1	21.752	39.223	Hogging	0.0012179	9.8388	0.033375	9056.4	-	0 (Negligible)
	Max Settlement	2	39.223	51.789	Sagging	0.0012179	16.31	0.021389	-	4135.1	0 (Negligible)
	Max Tensile Strain	1	21.752	39.223	Hogging	0.0012179	9.8388	0.033375	9056.4	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	21.752	39.223	Hogging	0.0012179	9.8388	0.033375	9056.4	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	2	39.223	51.789	Sagging	0.0012179	16.31	0.021389	-	4135.1	0 (Negligible)
B-18	Max Slope	1	0	6.7469	Sagging	9.03E-04	13.875	0.0064898	-	7690.5	0 (Negligible)
	Max Settlement	1	0	6.7469	Sagging	9.03E-04	13.875	0.0064898	-	7690.5	0 (Negligible)
	Max Tensile Strain	2	6.7469	27.825	Hogging	9.03E-04	8.8635	0.023928	14895	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	6.7469	27.825	Hogging	9.03E-04	8.8635	0.023928	14895	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-15	Max Slope	1	0	13.545	Sagging	5.45E-04	3.0917	0.021633	-	14937	0 (Negligible)
	Max Settlement	1	0	13.545	Sagging	5.45E-04	3.0917	0.021633	-	14937	0 (Negligible)
	Max Tensile Strain	1	0	13.545	Sagging	5.45E-04	3.0917	0.021633	-	14937	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-14	Max Slope	1	13.307	32.146	Hogging	0.0010034	8.9146	0.02538	12261	-	0 (Negligible)
	Max Settlement	2	32.146	50.075	Sagging	0.0010034	14.77	0.022883	-	5457.6	0 (Negligible)
	Max Tensile Strain	3	50.075	68.58	Hogging	0.0010017	8.9237	0.025531	12270	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	13.307	32.146	Hogging	0.0010034	8.9146	0.02538	12261	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	2	32.146	50.075	Sagging	0.0010034	14.77	0.022883	-	5457.6	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
B-13	Max Slope	1	0	3.2228	Sagging	1.30E-04	0.37572	0.00891	-	24394	0 (Negligible)
	Max Settlement	1	0	3.2228	Sagging	1.30E-04	0.37572	0.00891	-	24394	0 (Negligible)
	Max Tensile Strain	1	0	3.2228	Sagging	1.30E-04	0.37572	0.00891	-	24394	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-11	Max Slope	1	0	16.331	Hogging	9.43E-04	6.4691	0.025446	11659	-	0 (Negligible)
	Max Settlement	1	0	16.331	Hogging	9.43E-04	6.4691	0.025446	11659	-	0 (Negligible)
	Max Tensile Strain	1	0	16.331	Hogging	9.43E-04	6.4691	0.025446	11659	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	0	16.331	Hogging	9.43E-04	6.4691	0.025446	11659	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-12	Max Slope	1	0	11.186	Hogging	0.0014206	10.706	0.03748	7219.1	-	0 (Negligible)
	Max Settlement	2	11.186	21.876	Sagging	0.0014206	17.643	0.024623	-	3212.7	0 (Negligible)
	Max Tensile Strain	1	0	11.186	Hogging	0.0014206	10.706	0.03748	7219.1	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	0	11.186	Hogging	0.0014206	10.706	0.03748	7219.1	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	2	11.186	21.876	Sagging	0.0014206	17.643	0.024623	-	3212.7	0 (Negligible)
B-10	All vertical displacements are less than the limit sensitivity.										
B-7	All vertical displacements are less than the limit sensitivity.										
B-6	Max Slope	1	0	3.438	Sagging	5.74E-04	12.766	0.084645	-	371590	2 (Slight)
	Max Settlement	1	0	3.438	Sagging	5.74E-04	12.766	0.084645	-	371590	2 (Slight)
	Max Tensile Strain	2	3.438	3.6953	Sagging	5.66E-04	10.803	0.08561	-	266430	2 (Slight)
	Min Radius of Curvature (Hogging)	3	3.6953	33.169	Hogging	5.72E-04	10.657	0.057027	10238	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-5	All vertical displacements are less than the limit sensitivity.										
B-3	All vertical displacements are less than the limit sensitivity.										
B-4	All vertical displacements are less than the limit sensitivity.										
B-2	All vertical displacements are less than the limit sensitivity.										
B-52	Max Slope	1	0	6.7328	Sagging	7.06E-04	11.652	0.0042969	-	12272	0 (Negligible)
	Max Settlement	1	0	6.7328	Sagging	7.06E-04	11.652	0.0042969	-	12272	0 (Negligible)
	Max Tensile Strain	2	6.7328	28.742	Hogging	7.06E-04	7.5703	0.02584	20778	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	6.7328	28.742	Hogging	7.06E-04	7.5703	0.02584	20778	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-53	Max Slope	1	0	9.7159	Sagging	0.001586	26.299	0.016396	-	3834.6	0 (Negligible)
	Max Settlement	1	0	9.7159	Sagging	0.001586	26.299	0.016396	-	3834.6	0 (Negligible)
	Max Tensile Strain	2	9.7159	32.924	Hogging	0.001586	15.985	0.0522	8665.8	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	9.7159	32.924	Hogging	0.001586	15.985	0.0522	8665.8	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	1	0	9.7159	Sagging	0.001586	26.299	0.016396	-	3834.6	0 (Negligible)
B-55	Max Slope	1	0	1.3161	Sagging	0.0013944	14.552	0.0015107	-	24883	0 (Negligible)
	Max Settlement	1	0	1.3161	Sagging	0.0013944	14.552	0.0015107	-	24883	0 (Negligible)
	Max Tensile Strain	2	1.3161	15.476	Hogging	0.0013944	12.729	0.03766	8904.7	-	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Min Radius of Curvature (Hogging)	2	1.3161	15.476	Hogging	0.0013944	12.729	0.03766	8904.7	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-238	Max Slope	2	11.666	24.465	Sagging	0.0035255	37.127	0.084266	-	1106.5	2 (Slight)
	Max Settlement	2	11.666	24.465	Sagging	0.0035255	37.127	0.084266	-	1106.5	2 (Slight)
	Max Tensile Strain	1	0	11.666	Hogging	0.003512	22.526	0.091991	2510.6	-	2 (Slight)
	Min Radius of Curvature (Hogging)	3	24.465	39.758	Hogging	0.0035255	22.484	0.086642	2481.8	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	11.666	24.465	Sagging	0.0035255	37.127	0.084266	-	1106.5	2 (Slight)
B-147	Max Slope	1	0.63901	18.749	Hogging	0.0027837	21.409	0.082142	3797.9	-	2 (Slight)
	Max Settlement	2	18.749	34.225	Sagging	0.0027837	35.374	0.051998	-	1695.3	1 (Very Slight)
	Max Tensile Strain	1	0.63901	18.749	Hogging	0.0027837	21.409	0.082142	3797.9	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0.63901	18.749	Hogging	0.0027837	21.409	0.082142	3797.9	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	18.749	34.225	Sagging	0.0027837	35.374	0.051998	-	1695.3	1 (Very Slight)
B-148	Max Slope	1	0	10.529	Sagging	4.80E-04	2.1536	0.023084	-	11336	0 (Negligible)
	Max Settlement	1	0	10.529	Sagging	4.80E-04	2.1536	0.023084	-	11336	0 (Negligible)
	Max Tensile Strain	1	0	10.529	Sagging	4.80E-04	2.1536	0.023084	-	11336	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-149	Max Slope	1	0	0.80982	Sagging	0.0021328	20.392	0.0015888	-	26179	0 (Negligible)
	Max Settlement	1	0	0.80982	Sagging	0.0021328	20.392	0.0015888	-	26179	0 (Negligible)
	Max Tensile Strain	2	0.80982	19.331	Hogging	0.0021328	18.67	0.06187	5584.5	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	0.80982	19.331	Hogging	0.0021328	18.67	0.06187	5584.5	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-150	Max Slope	1	0	1.5245	Sagging	0.0014762	26.028	0.14025	-	46442	2 (Slight)
	Max Settlement	1	0	1.5245	Sagging	0.0014762	26.028	0.14025	-	46442	2 (Slight)
	Max Tensile Strain	1	0	1.5245	Sagging	0.0014762	26.028	0.14025	-	46442	2 (Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-228	Max Slope	1	0	16.33	Sagging	0.00727	31.844	0.031428	-	91.156	0 (Negligible)
	Max Settlement	1	0	16.33	Sagging	0.00727	31.844	0.031428	-	91.156	0 (Negligible)
	Max Tensile Strain	2	16.33	48.526	Hogging	0.0012618	19.772	0.098396	3586	-	2 (Slight)
	Min Radius of Curvature (Hogging)	2	16.33	48.526	Hogging	0.0012618	19.772	0.098396	3586	-	2 (Slight)
	Min Radius of Curvature (Sagging)	1	0	16.33	Sagging	0.00727	31.844	0.031428	-	91.156	0 (Negligible)
B-151	Max Slope	1	0	12.672	Sagging	0.0010204	37.218	0.096401	-	4181.7	2 (Slight)
	Max Settlement	1	0	12.672	Sagging	0.0010204	37.218	0.096401	-	4181.7	2 (Slight)
	Max Tensile Strain	1	0	12.672	Sagging	0.0010204	37.218	0.096401	-	4181.7	2 (Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	12.672	Sagging	0.0010204	37.218	0.096401	-	4181.7	2 (Slight)
B-152	Max Slope	1	0	9.235	Sagging	3.30E-04	2.6011	0.021665	-	32622	0 (Negligible)
	Max Settlement	1	0	9.235	Sagging	3.30E-04	2.6011	0.021665	-	32622	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Max Tensile Strain	1	0	9.235	Sagging	3.30E-04	2.6011	0.021665	-	32622	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
B-224	Max Slope	1	0	10.229	Sagging	6.21E-04	7.0642	0.018991	-	24743	0 (Negligible)
	Max Settlement	3	27.173	27.54	Sagging	3.06E-05	12.582	5.99E-04	-	577270	0 (Negligible)
	Max Tensile Strain	1	0	10.229	Sagging	6.21E-04	7.0642	0.018991	-	24743	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	2	10.229	27.173	Sagging	6.21E-04	12.571	0.0041408	-	17616	0 (Negligible)
B-222	Max Slope	2	6.7882	23.708	Sagging	8.24E-04	14.484	0.0080752	-	10437	0 (Negligible)
	Max Settlement	2	6.7882	23.708	Sagging	8.24E-04	14.484	0.0080752	-	10437	0 (Negligible)
	Max Tensile Strain	3	23.708	34.205	Sagging	8.24E-04	8.4375	0.025354	-	16823	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	2	6.7882	23.708	Sagging	8.24E-04	14.484	0.0080752	-	10437	0 (Negligible)
B-220	Max Slope	3	16.522	34.996	Sagging	6.81E-04	13.855	0.0056734	-	15493	0 (Negligible)
	Max Settlement	3	16.522	34.996	Sagging	6.81E-04	13.855	0.0056734	-	15493	0 (Negligible)
	Max Tensile Strain	4	34.996	58.729	Hogging	6.81E-04	7.9575	0.023997	23413	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	4	34.996	58.729	Hogging	6.81E-04	7.9575	0.023997	23413	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	3	16.522	34.996	Sagging	6.81E-04	13.855	0.0056734	-	15493	0 (Negligible)
B-217	Max Slope	1	0	25.628	Sagging	5.86E-04	19.464	0.0041474	-	9549.6	0 (Negligible)
	Max Settlement	1	0	25.628	Sagging	5.86E-04	19.464	0.0041474	-	9549.6	0 (Negligible)
	Max Tensile Strain	1	0	25.628	Sagging	5.86E-04	19.464	0.0041474	-	9549.6	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	25.628	Sagging	5.86E-04	19.464	0.0041474	-	9549.6	0 (Negligible)
AB-02	Max Slope	1	0	8.7803	Sagging	0.0011175	13.398	0.035983	-	14598	0 (Negligible)
	Max Settlement	2	8.7803	32.776	Sagging	0.0011175	22.094	0.011572	-	6516.5	0 (Negligible)
	Max Tensile Strain	3	32.776	51.319	Hogging	0.001116	13.407	0.050875	14662	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	3	32.776	51.319	Hogging	0.001116	13.407	0.050875	14662	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	8.7803	32.776	Sagging	0.0011175	22.094	0.011572	-	6516.5	0 (Negligible)
AB-03	Max Slope	1	0	12.11	Sagging	0.0014582	26.771	0.020748	-	3682	0 (Negligible)
	Max Settlement	1	0	12.11	Sagging	0.0014582	26.771	0.020748	-	3682	0 (Negligible)
	Max Tensile Strain	1	0	12.11	Sagging	0.0014582	26.771	0.020748	-	3682	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	12.11	Sagging	0.0014582	26.771	0.020748	-	3682	0 (Negligible)
AB-04	Max Slope	1	0	13.551	Sagging	0.0012988	26.679	0.016642	-	4580.6	0 (Negligible)
	Max Settlement	1	0	13.551	Sagging	0.0012988	26.679	0.016642	-	4580.6	0 (Negligible)
	Max Tensile Strain	1	0	13.551	Sagging	0.0012988	26.679	0.016642	-	4580.6	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	13.551	Sagging	0.0012988	26.679	0.016642	-	4580.6	0 (Negligible)
AB-05	Max Slope	1	0	0.91993	Sagging	0.0015964	16.112	0.0054187	-	40464	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Max Settlement	2	0.91993	13.069	Sagging	0.0015964	26.533	0.016326	-	3811.5	0 (Negligible)
	Max Tensile Strain	2	0.91993	13.069	Sagging	0.0015964	26.533	0.016326	-	3811.5	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	2	0.91993	13.069	Sagging	0.0015964	26.533	0.016326	-	3811.5	0 (Negligible)
AB-06	Max Slope	1	0	14.88	Hogging	0.0010602	12.732	0.041218	5968.6	-	0 (Negligible)
	Max Settlement	1	0	14.88	Hogging	0.0010602	12.732	0.041218	5968.6	-	0 (Negligible)
	Max Tensile Strain	1	0	14.88	Hogging	0.0010602	12.732	0.041218	5968.6	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	1	0	14.88	Hogging	0.0010602	12.732	0.041218	5968.6	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-07	Max Slope	1	0	16.065	Hogging	0.0020353	25.202	0.054918	2659.5	-	1 (Very Slight)
	Max Settlement	1	0	16.065	Hogging	0.0020353	25.202	0.054918	2659.5	-	1 (Very Slight)
	Max Tensile Strain	1	0	16.065	Hogging	0.0020353	25.202	0.054918	2659.5	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	0	16.065	Hogging	0.0020353	25.202	0.054918	2659.5	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-08	Max Slope	1	0	1.8523	Sagging	0.0032364	50.848	0.0057471	-	4794.2	0 (Negligible)
	Max Settlement	1	0	1.8523	Sagging	0.0032364	50.848	0.0057471	-	4794.2	0 (Negligible)
	Max Tensile Strain	2	1.8523	12.05	Hogging	0.0032364	44.975	0.062208	3407.7	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	1.8523	12.05	Hogging	0.0032364	44.975	0.062208	3407.7	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-09	Max Slope	3	14.161	16.395	Sagging	0.0010003	40.382	0.09518	-	46248	2 (Slight)
	Max Settlement	1	0	13.272	Sagging	9.78E-04	46.653	0.10245	-	2421	2 (Slight)
	Max Tensile Strain	1	0	13.272	Sagging	9.78E-04	46.653	0.10245	-	2421	2 (Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	13.272	Sagging	9.78E-04	46.653	0.10245	-	2421	2 (Slight)
AB-10	Max Slope	1	0	19.963	Hogging	0.0014678	27.844	0.072991	2921.3	-	1 (Very Slight)
	Max Settlement	1	0	19.963	Hogging	0.0014678	27.844	0.072991	2921.3	-	1 (Very Slight)
	Max Tensile Strain	1	0	19.963	Hogging	0.0014678	27.844	0.072991	2921.3	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	0	19.963	Hogging	0.0014678	27.844	0.072991	2921.3	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-11	Max Slope	1	0	1.742	Sagging	0.0042194	33.472	0.010536	-	2573.4	0 (Negligible)
	Max Settlement	1	0	1.742	Sagging	0.0042194	33.472	0.010536	-	2573.4	0 (Negligible)
	Max Tensile Strain	2	1.742	15.179	Hogging	0.0042194	26.327	0.15543	2013.9	-	3 (Moderate)
	Min Radius of Curvature (Hogging)	2	1.742	15.179	Hogging	0.0042194	26.327	0.15543	2013.9	-	3 (Moderate)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-12	Max Slope	1	0	8.5268	Sagging	0.0032141	42.626	0.038116	-	1220.1	0 (Negligible)
	Max Settlement	1	0	8.5268	Sagging	0.0032141	42.626	0.038116	-	1220.1	0 (Negligible)
	Max Tensile Strain	2	8.5268	14.322	Sagging	0.0032141	28.095	0.072528	-	3254	1 (Very Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	8.5268	Sagging	0.0032141	42.626	0.038116	-	1220.1	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
AB-13	Max Slope	1	0	6.9353	Hogging	0.0043934	26.713	0.13085	1889.3	-	2 (Slight)
	Max Settlement	2	6.9353	19.082	Sagging	0.0043934	44.01	0.055884	-	836.79	1 (Very Slight)
	Max Tensile Strain	3	19.082	29.532	Hogging	0.0043906	26.721	0.15526	1891.9	-	3 (Moderate)
	Min Radius of Curvature (Hogging)	1	0	6.9353	Hogging	0.0043934	26.713	0.13085	1889.3	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	6.9353	19.082	Sagging	0.0043934	44.01	0.055884	-	836.79	1 (Very Slight)
AB-14	Max Slope	1	0	10.97	Hogging	0.0040355	25.484	0.14551	2132.4	-	2 (Slight)
	Max Settlement	2	10.97	23.6	Sagging	0.0040355	42	0.049979	-	948.46	0 (Negligible)
	Max Tensile Strain	1	0	10.97	Hogging	0.0040355	25.484	0.14551	2132.4	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	10.97	Hogging	0.0040355	25.484	0.14551	2132.4	-	2 (Slight)
	Min Radius of Curvature (Sagging)	2	10.97	23.6	Sagging	0.0040355	42	0.049979	-	948.46	0 (Negligible)
AB-15	Max Slope	1	0	8.0493	Sagging	0.001724	23.073	0.049801	-	7631.2	0 (Negligible)
	Max Settlement	2	8.0493	11.386	Sagging	0.001724	28.581	0.0053888	-	7562.4	0 (Negligible)
	Max Tensile Strain	1	0	8.0493	Sagging	0.001724	23.073	0.049801	-	7631.2	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-16	Max Slope	1	0	11.629	Sagging	0.0015908	45.304	0.016074	-	3824.3	0 (Negligible)
	Max Settlement	1	0	11.629	Sagging	0.0015908	45.304	0.016074	-	3824.3	0 (Negligible)
	Max Tensile Strain	1	0	11.629	Sagging	0.0015908	45.304	0.016074	-	3824.3	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	11.629	Sagging	0.0015908	45.304	0.016074	-	3824.3	0 (Negligible)
AB-18	Max Slope	1	0	15.86	Sagging	7.83E-04	27.556	0.027756	-	13970	0 (Negligible)
	Max Settlement	1	0	15.86	Sagging	7.83E-04	27.556	0.027756	-	13970	0 (Negligible)
	Max Tensile Strain	1	0	15.86	Sagging	7.83E-04	27.556	0.027756	-	13970	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-19	Max Slope	2	6.5529	28.906	Sagging	4.64E-04	38.256	0.012214	-	32174	0 (Negligible)
	Max Settlement	2	6.5529	28.906	Sagging	4.64E-04	38.256	0.012214	-	32174	0 (Negligible)
	Max Tensile Strain	1	0	6.5529	Sagging	1.74E-04	38.143	0.08812	-	15255	2 (Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	2	6.5529	28.906	Sagging	4.64E-04	38.256	0.012214	-	32174	0 (Negligible)
AB-20	Max Slope	3	1.9353	16.75	Sagging	4.95E-04	24.685	0.024366	-	124400	0 (Negligible)
	Max Settlement	1	0	1.0956	Sagging	4.85E-04	25.499	4.87E-04	-	16928	0 (Negligible)
	Max Tensile Strain	6	20.749	32.798	Sagging	4.47E-04	16.271	0.031104	-	158050	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-21	Max Slope	1	0	6.526	Sagging	0.0014163	49.903	0.0041551	-	15875	0 (Negligible)
	Max Settlement	1	0	6.526	Sagging	0.0014163	49.903	0.0041551	-	15875	0 (Negligible)
	Max Tensile Strain	2	6.526	27.808	Hogging	0.0014163	40.993	0.010985	19798	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	6.526	27.808	Hogging	0.0014163	40.993	0.010985	19798	-	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-22	Max Slope	1	0	22.424	Sagging	8.37E-04	19.112	0.010526	-	10186	0 (Negligible)
	Max Settlement	1	0	22.424	Sagging	8.37E-04	19.112	0.010526	-	10186	0 (Negligible)
	Max Tensile Strain	2	22.424	26.373	Sagging	8.37E-04	11.551	0.010787	-	38501	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	22.424	Sagging	8.37E-04	19.112	0.010526	-	10186	0 (Negligible)
AB-23	Max Slope	1	0	16.973	Sagging	0.0010411	21.786	0.0081359	-	9024.8	0 (Negligible)
	Max Settlement	1	0	16.973	Sagging	0.0010411	21.786	0.0081359	-	9024.8	0 (Negligible)
	Max Tensile Strain	2	16.973	44.534	Hogging	0.0010411	12.8	0.043012	15966	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	16.973	44.534	Hogging	0.0010411	12.8	0.043012	15966	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	1	0	16.973	Sagging	0.0010411	21.786	0.0081359	-	9024.8	0 (Negligible)
AB-24	Max Slope	2	15.762	40.338	Sagging	0.0012886	26.406	0.010637	-	5755.4	0 (Negligible)
	Max Settlement	2	15.762	40.338	Sagging	0.0012886	26.406	0.010637	-	5755.4	0 (Negligible)
	Max Tensile Strain	3	40.338	63.333	Hogging	0.0012886	16.233	0.056124	12701	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	3	40.338	63.333	Hogging	0.0012886	16.233	0.056124	12701	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	15.762	40.338	Sagging	0.0012886	26.406	0.010637	-	5755.4	0 (Negligible)
AB-25	Max Slope	1	0	7.7602	Sagging	0.0015946	33.926	0.008312	-	4812.9	0 (Negligible)
	Max Settlement	1	0	7.7602	Sagging	0.0015946	33.926	0.008312	-	4812.9	0 (Negligible)
	Max Tensile Strain	2	7.7602	20.925	Hogging	0.0015946	23.391	0.042882	9778.4	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	7.7602	20.925	Hogging	0.0015946	23.391	0.042882	9778.4	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-28	Max Slope	1	0	19.714	Hogging	0.0020183	16.017	0.05814	5844.7	-	1 (Very Slight)
	Max Settlement	1	0	19.714	Hogging	0.0020183	16.017	0.05814	5844.7	-	1 (Very Slight)
	Max Tensile Strain	1	0	19.714	Hogging	0.0020183	16.017	0.05814	5844.7	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	0	19.714	Hogging	0.0020183	16.017	0.05814	5844.7	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-29	Max Slope	2	8.6666	23.542	Sagging	0.0030207	39.347	0.051693	-	1513.3	1 (Very Slight)
	Max Settlement	2	8.6666	23.542	Sagging	0.0030207	39.347	0.051693	-	1513.3	1 (Very Slight)
	Max Tensile Strain	2	8.6666	23.542	Sagging	0.0030207	39.347	0.051693	-	1513.3	1 (Very Slight)
	Min Radius of Curvature (Hogging)	1	0	8.6666	Hogging	0.0029303	25.313	0.046793	3476.2	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	2	8.6666	23.542	Sagging	0.0030207	39.347	0.051693	-	1513.3	1 (Very Slight)
AB-30	Max Slope	1	0	6.3483	Sagging	0.0030324	37.134	0.023689	-	1530.4	0 (Negligible)
	Max Settlement	1	0	6.3483	Sagging	0.0030324	37.134	0.023689	-	1530.4	0 (Negligible)
	Max Tensile Strain	2	6.3483	19.192	Hogging	0.0030324	22.95	0.08518	3379.4	-	2 (Slight)
	Min Radius of Curvature (Hogging)	2	6.3483	19.192	Hogging	0.0030324	22.95	0.08518	3379.4	-	2 (Slight)
	Min Radius of Curvature (Sagging)	1	0	6.3483	Sagging	0.0030324	37.134	0.023689	-	1530.4	0 (Negligible)
AB-31	Max Slope	1	0	15.346	Hogging	0.0028187	16.08	0.072972	3226.3	-	1 (Very Slight)
	Max Settlement	1	0	15.346	Hogging	0.0028187	16.08	0.072972	3226.3	-	1 (Very Slight)
	Max Tensile Strain	1	0	15.346	Hogging	0.0028187	16.08	0.072972	3226.3	-	1 (Very Slight)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Min Radius of Curvature (Hogging)	1	0	15.346	Hogging	0.0028187	16.08	0.072972	3226.3	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-32	Max Slope	1	0	16.149	Sagging	0.0021715	30.517	0.029775	-	2403.5	0 (Negligible)
	Max Settlement	1	0	16.149	Sagging	0.0021715	30.517	0.029775	-	2403.5	0 (Negligible)
	Max Tensile Strain	2	16.149	25.611	Hogging	0.0021715	18.525	0.056863	5339.4	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	16.149	25.611	Hogging	0.0021715	18.525	0.056863	5339.4	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	1	0	16.149	Sagging	0.0021715	30.517	0.029775	-	2403.5	0 (Negligible)
AB-33	Max Slope	1	0	3.4796	Sagging	9.48E-04	12.183	0.0028795	-	13271	0 (Negligible)
	Max Settlement	1	0	3.4796	Sagging	9.48E-04	12.183	0.0028795	-	13271	0 (Negligible)
	Max Tensile Strain	2	3.4796	23.897	Hogging	9.48E-04	9.0402	0.031288	13661	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	3.4796	23.897	Hogging	9.48E-04	9.0402	0.031288	13661	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-34	Max Slope	2	5.3995	18.86	Sagging	0.003608	40.089	0.064332	-	1130.5	1 (Very Slight)
	Max Settlement	2	5.3995	18.86	Sagging	0.003608	40.089	0.064332	-	1130.5	1 (Very Slight)
	Max Tensile Strain	3	18.86	24.623	Hogging	0.003608	24.345	0.067174	2546.9	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	3	18.86	24.623	Hogging	0.003608	24.345	0.067174	2546.9	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	5.3995	18.86	Sagging	0.003608	40.089	0.064332	-	1130.5	1 (Very Slight)
AB-35	All vertical displacements are less than the limit sensitivity.										
AB-36	Max Slope	1	0	7.3139	Sagging	1.63E-04	0.70858	0.0089075	-	31861	0 (Negligible)
	Max Settlement	1	0	7.3139	Sagging	1.63E-04	0.70858	0.0089075	-	31861	0 (Negligible)
	Max Tensile Strain	1	0	7.3139	Sagging	1.63E-04	0.70858	0.0089075	-	31861	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-37	Max Slope	2	4.0544	24.327	Sagging	7.79E-04	12.981	0.01294	-	7883.7	0 (Negligible)
	Max Settlement	2	4.0544	24.327	Sagging	7.79E-04	12.981	0.01294	-	7883.7	0 (Negligible)
	Max Tensile Strain	2	4.0544	24.327	Sagging	7.79E-04	12.981	0.01294	-	7883.7	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	2	4.0544	24.327	Sagging	7.79E-04	12.981	0.01294	-	7883.7	0 (Negligible)
AB-38	Max Slope	1	0	5.2867	Sagging	0.0012192	17.717	0.0063204	-	6977.5	0 (Negligible)
	Max Settlement	1	0	5.2867	Sagging	0.0012192	17.717	0.0063204	-	6977.5	0 (Negligible)
	Max Tensile Strain	2	5.2867	18.495	Hogging	0.0012192	11.955	0.03693	10945	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	5.2867	18.495	Hogging	0.0012192	11.955	0.03693	10945	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB-39	Max Slope	2	5.8578	23.591	Sagging	0.0020808	30.204	0.032496	-	2606.8	0 (Negligible)
	Max Settlement	2	5.8578	23.591	Sagging	0.0020808	30.204	0.032496	-	2606.8	0 (Negligible)
	Max Tensile Strain	3	23.591	44.135	Hogging	0.0020808	18.257	0.069875	5750.9	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	3	23.591	44.135	Hogging	0.0020808	18.257	0.069875	5750.9	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	2	5.8578	23.591	Sagging	0.0020808	30.204	0.032496	-	2606.8	0 (Negligible)
AB-40	Max Slope	1	0	2.1745	Sagging	0.0016619	20.237	0.0029606	-	13806	0 (Negligible)

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
	Max Settlement	1	0	2.1745	Sagging	0.0016619	20.237	0.0029606	-	13806	0 (Negligible)
	Max Tensile Strain	2	2.1745	17.738	Hogging	0.0016619	16.683	0.057303	8214.2	-	1 (Very Slight)
	Min Radius of Curvature (Hogging)	2	2.1745	17.738	Hogging	0.0016619	16.683	0.057303	8214.2	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB 44	Max Slope	8	5.8881	11.601	Sagging	9.95E-04	21.419	0.11257	-	1153.2	2 (Slight)
	Max Settlement	8	5.8881	11.601	Sagging	9.95E-04	21.419	0.11257	-	1153.2	2 (Slight)
	Max Tensile Strain	5	1.39	2.9758	Sagging	5.76E-04	14.906	0.12859	-	69207	2 (Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB 45	Max Slope	1	0	12.218	Hogging	0.0015187	25.785	0.092495	1296.7	-	2 (Slight)
	Max Settlement	1	0	12.218	Hogging	0.0015187	25.785	0.092495	1296.7	-	2 (Slight)
	Max Tensile Strain	1	0	12.218	Hogging	0.0015187	25.785	0.092495	1296.7	-	2 (Slight)
	Min Radius of Curvature (Hogging)	1	0	12.218	Hogging	0.0015187	25.785	0.092495	1296.7	-	2 (Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB 46	Max Slope	1	0	15.92	Sagging	0.0014667	24.501	0.086431	-	1634.3	2 (Slight)
	Max Settlement	1	0	15.92	Sagging	0.0014667	24.501	0.086431	-	1634.3	2 (Slight)
	Max Tensile Strain	1	0	15.92	Sagging	0.0014667	24.501	0.086431	-	1634.3	2 (Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB 47	Max Slope	1	0	7.4859	Sagging	0.0010132	33.229	0.087613	-	8407.7	2 (Slight)
	Max Settlement	1	0	7.4859	Sagging	0.0010132	33.229	0.087613	-	8407.7	2 (Slight)
	Max Tensile Strain	1	0	7.4859	Sagging	0.0010132	33.229	0.087613	-	8407.7	2 (Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB 48	Max Slope	3	19.119	20.368	Sagging	3.71E-04	10.021	0.054756	-	6587.8	1 (Very Slight)
	Max Settlement	5	24.752	25.818	Sagging	2.77E-04	11.786	0.064221	-	327210	1 (Very Slight)
	Max Tensile Strain	4	20.368	24.752	Sagging	3.71E-04	11.492	0.084839	-	11198	2 (Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB 49	Max Slope	1	0	13.028	Sagging	3.50E-04	15.07	0.059619	-	4160	1 (Very Slight)
	Max Settlement	1	0	13.028	Sagging	3.50E-04	15.07	0.059619	-	4160	1 (Very Slight)
	Max Tensile Strain	1	0	13.028	Sagging	3.50E-04	15.07	0.059619	-	4160	1 (Very Slight)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
AB 50	Max Slope	1	0	7.9267	Sagging	0.0010014	29.707	0.13046	-	14944	2 (Slight)
	Max Settlement	1	0	7.9267	Sagging	0.0010014	29.707	0.13046	-	14944	2 (Slight)
	Max Tensile Strain	1	0	7.9267	Sagging	0.0010014	29.707	0.13046	-	14944	2 (Slight)
	Min Radius of Curvature (Hogging)	4	17.875	54.177	Hogging	8.42E-04	13.123	0.070923	6675.1	-	1 (Very Slight)
	Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-

Specific Building	Parameter	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
AB 51	Max Slope	1	0	15.504	Sagging	8.02E-04	13.309	0.0081188	-	7582	0 (Negligible)
	Max Settlement	1	0	15.504	Sagging	8.02E-04	13.309	0.0081188	-	7582	0 (Negligible)
	Max Tensile Strain	2	15.504	18.71	Sagging	8.02E-04	8.0748	0.0097322	-	25276	0 (Negligible)
	Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
	Min Radius of Curvature (Sagging)	1	0	15.504	Sagging	8.02E-04	13.309	0.0081188	-	7582	0 (Negligible)
AB 52	Max Slope	1	0	19.402	Sagging	7.63E-04	13.092	0.0073983	-	8340.5	0 (Negligible)
	Max Settlement	1	0	19.402	Sagging	7.63E-04	13.092	0.0073983	-	8340.5	0 (Negligible)
	Max Tensile Strain	2	19.402	41.582	Hogging	7.63E-04	7.9389	0.030496	18599	-	0 (Negligible)
	Min Radius of Curvature (Hogging)	2	19.402	41.582	Hogging	7.63E-04	7.9389	0.030496	18599	-	0 (Negligible)
	Min Radius of Curvature (Sagging)	1	0	19.402	Sagging	7.63E-04	13.092	0.0073983	-	8340.5	0 (Negligible)